GIS-BASED SUPPORT FOR IMPLEMENTING POLICIES AND PLANS TO INCREASE ACCESS TO ENERGY SERVICES IN GHANA

Final Report

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## Abbreviations

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<th>TERM</th>
<th>DEFINITION</th>
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<tbody>
<tr>
<td>CWIQ</td>
<td>Core Welfare Indicators Questionnaire</td>
</tr>
<tr>
<td>DSS</td>
<td>Decision Support System</td>
</tr>
<tr>
<td>EAD</td>
<td>Energy Access Data</td>
</tr>
<tr>
<td>EAGeo-database</td>
<td>Energy Access Geo-database</td>
</tr>
<tr>
<td>EC</td>
<td>Energy Commission</td>
</tr>
<tr>
<td>ECG</td>
<td>Electricity company of Ghana</td>
</tr>
<tr>
<td>ECEWAS</td>
<td>Economic Community of West African States</td>
</tr>
<tr>
<td>ECREEEE</td>
<td>ECOWAS Center for Renewable Energy and Energy Efficiency</td>
</tr>
<tr>
<td>EPRAP</td>
<td>Energy for Poverty Reduction Action Plan</td>
</tr>
<tr>
<td>EUEI</td>
<td>European Union Energy Initiative</td>
</tr>
<tr>
<td>EUEI-PDF</td>
<td>European Union Energy Initiative – Partnership Dialogue Facility</td>
</tr>
<tr>
<td>GDB</td>
<td>Geo-Database</td>
</tr>
<tr>
<td>GEAR</td>
<td>GIS-based Energy Access Review</td>
</tr>
<tr>
<td>GEDAP</td>
<td>Ghana Energy Development and Access Project</td>
</tr>
<tr>
<td>GIS</td>
<td>Geographic Information System</td>
</tr>
<tr>
<td>GIS-EAP</td>
<td>Geographic Information Systems Energy Access Project</td>
</tr>
<tr>
<td>GLSS</td>
<td>Ghana Living Standards Survey</td>
</tr>
<tr>
<td>GRIDCO</td>
<td>Ghana Grid Company</td>
</tr>
<tr>
<td>GSS</td>
<td>Ghana Statistical Service</td>
</tr>
<tr>
<td>GUI</td>
<td>Graphic User Interface</td>
</tr>
<tr>
<td>HH</td>
<td>Household</td>
</tr>
<tr>
<td>interHH</td>
<td>inter-Household</td>
</tr>
<tr>
<td>JICA</td>
<td>Japan International Cooperation Agency</td>
</tr>
<tr>
<td>KNUST</td>
<td>Kwame Nkrumah University of Science and Technology</td>
</tr>
<tr>
<td>LCOE</td>
<td>Levelised Cost of Electrification</td>
</tr>
<tr>
<td>LPG</td>
<td>Liquefied Petroleum Gas</td>
</tr>
<tr>
<td>LV</td>
<td>Low Voltage</td>
</tr>
<tr>
<td>MDGs</td>
<td>Millennium Development Goals</td>
</tr>
<tr>
<td>MDI</td>
<td>Multiple Document interface</td>
</tr>
<tr>
<td>MID</td>
<td>Mean Inter-Household Distance</td>
</tr>
<tr>
<td>MMI</td>
<td>Man-Machine Interface</td>
</tr>
<tr>
<td>MoEn</td>
<td>Ministry of Energy</td>
</tr>
<tr>
<td>MV</td>
<td>Medium Voltage</td>
</tr>
<tr>
<td>MWp</td>
<td>Peak Megawatt</td>
</tr>
<tr>
<td>NED</td>
<td>Northern Electricity Department</td>
</tr>
<tr>
<td>NEPAD</td>
<td>New Partnership for Africa’s Development</td>
</tr>
<tr>
<td>NES</td>
<td>National Electrification Scheme</td>
</tr>
<tr>
<td>NESRP</td>
<td>Northern Electrification and System Reinforcement Project</td>
</tr>
<tr>
<td>PR</td>
<td>Penetration Rates</td>
</tr>
<tr>
<td>PV</td>
<td>Photovoltaic</td>
</tr>
<tr>
<td>RDBMS</td>
<td>Relational Database Management System</td>
</tr>
<tr>
<td>Acronym</td>
<td>Description</td>
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<td>---------</td>
<td>--------------------------------------------</td>
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<tr>
<td>SHEP</td>
<td>Self-Help Electrification Project</td>
</tr>
<tr>
<td>SNEP</td>
<td>Strategic National Energy Plan</td>
</tr>
<tr>
<td>TEC</td>
<td>The Energy Center</td>
</tr>
<tr>
<td>TM</td>
<td>Transverse Mercator</td>
</tr>
<tr>
<td>UNDP</td>
<td>United Nations Development Programme</td>
</tr>
<tr>
<td>UTM</td>
<td>Universal Transverse Mercator</td>
</tr>
<tr>
<td>VRA-NED</td>
<td>Volta River Authority – Northern Electricity Department</td>
</tr>
<tr>
<td>WIMP</td>
<td>Windows, Icons, Menus and Pointing</td>
</tr>
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</table>
Executive Summary

Background to Project

One of the significant drivers of socio-economic development of a country is the country’s access to energy. The importance of access to electricity compared to other forms of energy is so enormous. For instance, its contribution to health, education, agriculture and environmental sustainability has facilitated human development. Moreover and particularly in the rural areas, access to electricity has helped to reduce time and efforts spend (especially by women and children) in the collection of other fuel such as kerosene for lighting; and has also reduced rural to urban migration in search for jobs and modern facilities. In addition, potential benefits of electricity in rural areas include crop irrigation, agro-processing and preservation of farm produce.

Ghana’s energy policy aims at ensuring reliable and cost-effective supply of high quality energy services for households, businesses, industries and the transport sector nationwide. The need to secure future electricity and modern fuel supplies has been touted as the pivot of the Millennium Development Goals (MDGs). However, in spite of the popular notion underpinning energy access-poverty reduction nexus, policies and plans intended to create enabling environment for an improved energy access are seldom evaluated in most developing countries.

This report encapsulates the activities undertaken under a project dubbed ‘GIS-based Support for Implementing Policies and Plans to Increase Access to Energy Services in Ghana’ and its recommendations. The project was undertaken by The Energy Center (TEC) of Kwame Nkrumah University of Science and Technology (KNUST) with funding from the European Union Energy Initiative – Partnership Dialogue Facility (EU-EI-PDF) to ensure timely cross-sectoral coordination of plans and data. The assessment sought to employ and complement existing policies, strategies, plans and recommendations from the Energy for Poverty Reduction Action Plan (EPRAP) and the Ghana Energy Development and Access Project (GEDAP) to achieve national goals and the MDGs, and is a pilot project whose results shall be replicated in other countries of the ECOWAS Sub-region.

Project Objectives

The objectives of the project were:

1. To review existing energy policies, strategies and plans for increasing energy access in Ghana with reference to the targets set in the Government’s policy statements/documents, the ECOWAS White Paper and the MDGs.

2. To use GIS to collate and analyze national level data and provide timely information on population distribution, services, economic activities, and status of energy access programs.
3. To identify the gaps in energy policies and plans for achieving expected energy access targets by 2020 and proffer timely mitigation measures.

4. To develop methods and tools to facilitate business models, investment plans and capacity development to complement current planned activities to achieve the energy access targets by 2015.

5. To facilitate project identification, planning implementation and impact assessment for the Energy Commission of Ghana, the Ghana Ministry of Energy and the ECOWAS Commission for timely development, implementation and monitoring of energy access strategies.

**Review of Energy Trends, Policies and Plans in Ghana**

The intent of the energy policy review was to assess the trends, policies, plans and programmes developed over the years to ensure increased access to energy services in Ghana by 2020 and beyond. The review found that there has been a remarkable growth in electricity supply from the late 1990s buoyed by the National Electrification Scheme (NES) and later the Self Help Electrification Programme (under the NES). This has raised electricity access rates to about 72% in 2010 (Figure 1), a feat only rivalled by Cape Verde and South Africa in sub-Saharan Africa, but with disparity in rural and urban areas. Disturbingly, biomass in the form of woodfuel, remain the most prominent fuel in Ghana for cooking and heating. Firewood and charcoal contribute about 63% to the total energy consumed in the country and is a major source of worry considering the effects on deforestation and the health problems associated with indoor pollution from the use of biomass. Even though some strides have been made in LPG consumption in urban areas, especially in the Ashanti and Greater Accra Regions, access to LPG is still lower than expected and even worse in the rural areas. Renewable energy has not made much contribution to the energy mix in Ghana. Gains in solar PV have been modest when compared to the country’s potential. Wind energy and small hydro resources have not been exploited fully and biofuel programmes are still in the feedstock stage with little to show in terms of the production of commercial fuels.

Ghana faces several challenges which frustrate efforts to achieve national energy access targets and goals. These challenges include growing demand for energy but with inadequate investment to match the demand, high levels of end-use inefficiency culminating in waste of final energy forms and inefficient pricing of energy services resulting in poor financial positions of the energy providers. Other challenges are operational inefficiencies of the utilities leading to high energy losses (averaging about 26.8% over the past ten years), under-exploitation of renewable energy sources and over reliance on woodfuels which could threatens the country’s forest cover.

There have been several plans, policies and programmes aimed at increasing access to energy services in Ghana over the last few decades. Governments over the years have had the provision of energy services high on the developmental agenda but despite the good intentions of all these governments to increase access to energy services, existing policies
and plans have not delivered the best results, especially in the rural areas. Policies aimed, especially at reducing biomass usage and promoting environment friendly cooking fuels, have achieved very little results.

Figure 1: National, urban and rural electricity access rates for Ghana

Assessment of Energy Needs and Comparison with ECOWAS targets and MDGs

A comparative analysis of the country’s electricity access with ECOWAS targets reveals that, Ghana has made significant strides. As of mid-2010, Ghana had surpassed the ECOWAS rural electricity targets of 36% access and is close to achieving the 100% urban access by 2015 (Figure 2). More so, Ghana is placed second to only Cape Verde in terms of electricity access and ranked higher than Nigeria, Cote d’Ivoire and Senegal given an estimated electricity access rate of 72% (percent of population) in 2010 (see Figure 4.2). However, Ghana’s impressive electricity access rates have not translated into increased access to modern fuels for cooking and heating as countries like Cape Verde and Senegal. Access rates available for 2008 indicate that access to modern fuels in Ghana was only 12% as compared to Senegal’s 41% and Cape Verde’s 63%. Ghana’s current access rate to modern fuels implies that it is not likely that the country will be able to achieve the ECOWAS target of 100% by 2015. The implication is that, the use of unclean energy sources (wood fuel and charcoal) and their dire consequences will continue to make a large proportion of the population vulnerable to numerous health risks as well as suffer the consequence of derailing the achievement of MDGs.
Addressing MDGs through access to modern cooking fuel (especially LPG) for cooking remain a serious development challenge. Low access to modern cooking fuels presupposes the continuous use of traditional biomass with their associated health risks. The LPG access rate is far below the ECOWAS target of 50% for modern cooking fuels and the MDG target of reducing to 50% of those without access to LPG set by United Nation’s Millennium Project.

There is scant data on improved cook stoves in the country. It is therefore difficult to measure how their availability is making up for the limited LPG use in the country. The low access rate to cleaner cooking fuels may therefore present a potential threat to achieving the MDGs. The situation is likely to be worsened in the Northern, Upper East and Upper West regions of Ghana where access to LPG is extremely low. Although the number of LPG station access across Ghana is inadequate, the situation in the three Northern regions (Upper East, Northern and Upper West) is very bleak as the few LPG stations are concentrated in the regional capitals. The difficulty of access to LPG by remote settlements (from the regional capitals) is evident in the large land areas/sizes of the regions coupled with the persistent transportation problems. This presupposes the high dependence on traditional biomass in the aforementioned regions.

**Development of GIS e-maps for Energy Services**

GIS e-maps for social services and amenities have been prepared and the data mapped include Electricity Company of Ghana substations, location of mini-hydro dams, potential wind sites, solar radiation, access to electricity in basic schools, access to electricity by hospitals and clinics and access to biogas. Geo-processing operations have been carried out on the base maps using the WGS1984 UTM Zone 30N and 30S geographic projections. All the maps have been exported to the JPEG format which can be opened on all computers with a
Development of Methods and Tools for Capacity Building

Electrification costs modelling

One of the key objectives of the GIS-EAP project was to develop methods and tools to analyse Ghana’s energy access situation for capacity building of energy stakeholders in the country. The project team adopted a modelling tool called Network Planner developed by the Earth Institute of Columbia University to model electrification costs for un-electrified communities in the country. The network planner can be used to rapidly estimate connection costs and compare different regions and communities. The model determines the least-cost technology – either grid electrification or an off-grid alternative – to connect a community. The policy relevance of the model is to help planners estimate investment costs and financing requirements to support electrification programs and identify opportunities for cost-effective grid expansion.

The modelling was done on a regional basis to understand the total cost of electrification for the un-electrified communities in each region since each region has different characteristics of some of the inputs model parameter that have to be considered. In this study, the year 2010 was chosen to be the base year with a time horizon of ten (10) years due to the country’s energy target of universal electrification in 2020. All the input model data were acquired in 2010 except the population data of the un-electrified communities which were projected from the year 2000 to the year 2010 using a population growth rate proposed by the Ghana Statistical Services.

The results obtained from the base scenario which represents the best estimates of parameters and assumptions used in modelling the un-electrified communities in each region are summarised in Table 1. The results are shown for 30%, 60% and 100% penetration rates.

The cost of electrification differs widely across the ten regions due to remoteness (distance from existing electricity grid network), size (land area), the number of non-electrified communities coupled with large population size and the projected electricity demand over the ten years time horizon. The scattered pattern of settlement in Northern Ghana and the existence of many non-electrified communities amply suffice the relatively high electrification cost compared to other regions especially Greater Accra region which has the reverse characteristics. The availability of such electrification cost ranges provide a useful
guide to the financing mechanisms or investments required either from private sectors or the government to achieve a certain level of penetration rate and eventually universal access (100%) by 2020. Sensitivity analyses were performed to determine the effect of changes in some of the key parameters on the costs of electrification.

Table 1: Total cost of all combined electrification technologies at each penetration rate

<table>
<thead>
<tr>
<th>Region</th>
<th>No. of un-electrified Communities</th>
<th>Cost Of ALL ELECTRIFICATION, US$ (Grid, Solar off-grid and Diesel mini-grid)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ashanti</td>
<td>221</td>
<td>*PR = 100% 61,127,135</td>
</tr>
<tr>
<td>Brong Ahafo</td>
<td>195</td>
<td>*PR = 100% 61,307,042</td>
</tr>
<tr>
<td>Central</td>
<td>175</td>
<td>*PR = 100% 57,147,309</td>
</tr>
<tr>
<td>Eastern</td>
<td>247</td>
<td>*PR = 100% 49,849,486</td>
</tr>
<tr>
<td>Greater Accra</td>
<td>11</td>
<td>*PR = 100% 2,859,040</td>
</tr>
<tr>
<td>Northern</td>
<td>660</td>
<td>*PR = 100% 147,276,999</td>
</tr>
<tr>
<td>Upper East</td>
<td>299</td>
<td>*PR = 100% 61,635,747</td>
</tr>
<tr>
<td>Upper West</td>
<td>294</td>
<td>*PR = 100% 68,720,385</td>
</tr>
<tr>
<td>Volta</td>
<td>179</td>
<td>*PR = 100% 84,270,636</td>
</tr>
<tr>
<td>Western</td>
<td>319</td>
<td>*PR = 100% 101,646,482</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>2600</strong></td>
<td><strong>695,840,261</strong></td>
</tr>
</tbody>
</table>

*PR = Penetration Rate

**GIS-based Energy Access Review (GEAR) Toolkit**

Proper re-structuring and the provision of up-to-date information on energy issues are needed to inform energy policy formulation. The GIS-Based Energy Access Review (GEAR) Toolkit (Figure 3) focused on the development of a platform that can enable users get information pertaining to electrified and non-electrified communities in Ghana. The Toolkit is intended to partly display results of the modelling exercise as well as Liquefied Petroleum Gas (LPG) data in Ghana and show electrification trends in the country in order to facilitate planning.
Figure 3: GEAR Toolkit login interface

The production of a digital map and a functional geo-database of the facilities would assist adequately in the adequate distribution of energy in the following areas: Creation of a geo-database (spatial/attribute) for the features for updating, based on their conditions; capturing of the geometric and attribute data of electrified and un-electrified communities; update and modification of information concerning facilities for electricity distribution such as electrified and non-electrified communities in Ghana; faster and easier retrieval of information for instantaneous use in the area of planning, managing and monitoring of electrified communities as well as the trend of LPG access in communities.

The GEAR toolkit allows a user or a planner to interrogate (query) the system to obtain a piece of information such as electrified and un-electrified communities with their corresponding spatial units. In the Toolkit application, electrified or un-electrified settlements can be displayed on a map. To make an emphasis on a particular population centre (settlement) of interest like un-electrified settlements, the user must select from a drop-down button to make the query of interest; in this case 'un-electrified' and then press the query button for the programme to display the output. The user can then flash the output to know the locations of those settlements that met the query. The output will pop-up repeatedly in a brighter light. The system can also give a graphical report on electricity access rate for a community/town, district, and region or even at a national scale. The percentage of the communities with or without access to electricity, distance between towns (as a crow flies) and so on could be displayed in the programme. The application could be installed onto a server and then networked for use at a local level without necessarily having an internet connection and without the need for any proprietary software. Users only have to be registered before accessing the system. Users of the program could be a lay man,
a district planner, the utilities, Energy Commission, Ministry of Energy and their allied agencies.

Conclusions and Recommendations

The review and assessment carried out has shown that Ghana has made significant strides in electricity access due to long-range energy planning with clear targets, availability of external funding, political/popular demand and active role of central government in the implementation of energy policies. With urban electricity access rate of about 99% and rural access of 49%, the country has made a very good progress when compared with the ECOWAS target values of 100 for urban and 36% for rural households by 2015. This suggests that, Ghana is well on the way to meeting the ECOWAS targets for electricity especially in higher-income regions like Greater Accra and Ashanti.

Access rate to LPG is low, at approximately 12%. Due to the health effects of traditional cooking fuels, the low LPG access rate present a potential threat to achieving the MDGs. Generally, LPG stations in the country are inadequate to meet the rising demand and recent shortages have even compounded the problem. Current trends indicate that government may not be able to meet its LPG target of 50% access by the year 2015.

This project has shown, with the aid of electrification modelling, that by the end of the ten year planning period (2020), the majority of un-electrified communities will be viable for grid expansion with some small percentage number being off-grid compatible. This is due to the Ghana’s pre-existing network coverage reaching the whole country (at least running through every district capital in each region).

The GEAR Toolkit developed in this project will serve as a tool to manage energy access data for Ghana and facilitate easy planning and capacity building. A user can find information on whether a community is electrified, the population of the community, the spatial coordinates of the community, grid installation cost (US$) and proposed electrification technology for the community if it is un-electrified, etc.

There is the need to ensure a proper integration of Solar PV and other renewable energy systems into electrification programmes at both national and sub-national levels. In some cases, as with most parts of Ghana, grid-connected solar PV systems can be employed so that the problems associated with the promotion of off-grid electrifications options in soon-to-be-electrified areas would be avoided or at least reduced.

There is a need for more studies to generate a database for determining the pattern of energy access improvement over the years, challenges and prospects as well as the main drivers of energy access in the country. This will help provide useful information for accurate projections about how to achieve a certain time-bound access rate given certain sets of prevailing conditions especially on LPG.

The project proposed the setting up of an Energy Access Data (EAD) Task Force. The intent of the proposed EAD Task Force is to facilitate the development of a shared database using
harmonized methodologies on access to electricity and LPG in Ghana. The project director has recommended the formation of the EAD to the Minister of Energy and a forum for Energy-sector Board Chairs and CEOs and they have agreed to form the EAD Task Force. The EAD Task Force will initially consist of the following agencies (with the power to co-opt additional members as needed):

1. Energy Commission (Convener and Chair);
2. National Petroleum Authority;
3. Volta River Authority /Northern Electricity Department;
4. Electricity Company of Ghana;
5. Ghana Statistical Service;
6. The Energy Center, KNUST
7. CERSGIS, University of Ghana

This project recommends Msc/Mphil and PhD research works to address data gaps and to complement extant studies. The project also recommends further research into the energy demands by specific sectors of the economy such as health and education to facilitate sectoral energy access evaluation. In particular, it is recommended that further studies be undertaken on the availability of improved cook stoves in households and the improvements made so far across the ten regions of Ghana.
1 Introduction

1.1 Project background

One of the significant drivers of socio-economic development of a country is the country’s access to electricity. The importance of access to electricity compared to other forms of energy is so enormous. For instance, its contribution to health, education, agriculture and environmental sustainability has facilitated human development. Moreover and particularly in the rural areas, access to electricity has helped reduce rural-urban migration in search for jobs and modern facilities. In addition, potential benefits of electricity in rural areas include crop irrigation, agro-processing and preservation of farm produce.

Despite its enormous importance, about a quarter of the world populations (1.6 billion) live without access to electricity. Most of the people without electricity are found in the rural areas of the developing world, mainly South East Asia and sub-Saharan Africa. In sub-Saharan Africa, rural electrification rate remains at a single digit. A recent projection of obtaining 100% electrification in the sub-Saharan Africa will be achieved in the year 2087 or later even with the rapid increase in population. In spite of the challenges to the electricity access in sub-Saharan Africa, Ghana has made a remarkable progress to the electricity accessibility rate. In Ghana, a recent study carried out by the Ministry of Energy as of mid-2010 has estimated the electricity access rate (based on the population of communities that have access) at approximately 72% with urban rate of almost 100% and rural rate of about 49%.

Ghana’s energy policy aims at ensuring reliable and cost-effective supply of high quality energy services for households, businesses, industries and the transport sector nationwide. The need to secure future electricity and modern fuel supplies has been touted as the pivot of the Millennium Development Goals (MDGs). However, in spite of the popular notion underpinning energy access-poverty reduction nexus, policies and plans intended to create enabling environment for an improved energy access are seldom evaluated in most developing countries.

For an effective assessment of the energy access in Ghana, Geographic Information System (GIS) planning tools was thought necessary for a timely analysis and review of population and service distribution (such as improved heating/drying systems, cook stoves, Liquefied Petroleum Gas (LPG) distribution and mechanical power), grid-extension, mini-grid and off-grid plans. This method is useful because it seeks to provide data and analysis to enable policy makers, private sector and development partners like European Union Energy Initiative (EUEI), United Nations Development Programme (UNDP) and the World Bank as well as regional organizations such as the Economic Community of West African States (ECOWAS) to determine the additional measures or adaptations that will be needed to achieve the energy access targets of Ghana.
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The Geographic Information Systems (GIS) based Energy Access Project (GIS-EAP) was undertaken by The Energy Center (TEC) of Kwame Nkrumah University of Science and Technology (KNUST) with funding from the European Union Energy Initiative – Partnership Dialogue Facility (EUEI-PDF) to ensure timely cross-sectoral coordination of plans and data. The assessment sought to employ and complement existing policies, strategies, plans and recommendations from the Energy for Poverty Reduction Action Plan (EPRAP) and the Ghana Energy Development and Access Project (GEDAP) to achieve national goals and the MDGs. It is a pilot project whose results shall be replicated in other countries of the ECOWAS Sub-region.

1.2 Project objectives

The general objective of the GIS-EAP project was to contribute towards effective implementation of policies and plans for achieving energy access targets by 2015 through continuous review and adaptation. Specific objectives that sought to address the overall objective of the project were:

1. To review existing energy policies, strategies and plans for increasing energy access in Ghana with reference to the targets set in the Government’s policy statements/documents, the ECOWAS White Paper and the MDGs.

2. To use GIS to collate and analyze national level data and provide timely information on population distribution, services, economic activities, and status of energy access programs.

3. To identify the gaps in energy policies and plans for achieving expected energy access targets by 2020 and proffer timely mitigation measures.

4. To develop methods and tools to facilitate business models, investment plans and capacity development to complement current planned activities to achieve the energy access targets by 2015.

5. To facilitate project identification, planning implementation and impact assessment for the Energy Commission of Ghana, the Ghana Ministry of Energy and the ECOWAS Commission for timely development, implementation and monitoring of energy access strategies.

1.3 Expected Outcomes

The following items were expected at the end of the project period:

1. Existing energy policies, strategies, planning tools for energy access needs should have been identified and reviewed.

2. Using GIS tools, national level data on population distribution with information on social services, economic activities, and planned energy services should be assessed and energy access gaps identified and compared with the targets set in the Government’s policy statements/documents, the ECOWAS White Paper and the MDGs.
3. Methods and tools should have been developed to facilitate business models, additional resources, investment plans, associated costs and capacity development to complement current planned activities to achieve the energy access targets by 2015.

4. Planning tools and needs analysis methodology are made available to the Ghana Energy Commission, Ghana Ministry of Energy and their allied agencies as well as the ECOWAS Commission for dissemination to similar institutions in member states.

5. Proposals are developed to continuously update the data to enable it to be used for monitoring and implementation.

6. Templates for data collection, planning and review for energy access programmes are made available to the ECOWAS Commission in both hard and soft formats.

1.4 Scope of study
Earlier in the project, the project team deliberated on the scope of the project as to whether to select one region for the study or select the entire country. After several deliberations, it was decided to conduct the study for the entire country rather than make it a regional case study. It was thought that conducting the study for the country as a whole would present interesting scenarios for the various regions and enable comparison among regions in order to establish the factors that drive or delay access to energy access in the various regions of the country.

1.5 Structure of report
Following this introduction, section two presents the methodology and approach for implementing the project. Section three sets a thrilling pace for the achievement of the project objectives by illuminating a review of Ghana’s energy policy decisions and plans. Section four measures Ghana’s energy situation at a sub-regional and even global level by making a comparative assessment with the energy targets set by ECOWAS and Millennium Development Goals (MDGs). Section five focuses on the development of GIS e-maps and scenarios for energy services in Ghana. Section six analyses the methods and tools developed for capacity development. Section seven looks at the sensitization workshop organized for the planning officers of the various districts, municipal and metropolitan assemblies in Ghana as well as training conducted for Ghana’s Ministry of Energy and allied agencies and ECOWAS member countries on the results of the GIS project. The training was undertaken in the month of August, 2011 following the completion of GIS-maps, GEAR Toolkit and major findings of the GIS-EAP project. The final section provides a synopsis of the key issues that have emerged from the project from which recommendations are made.
2 Project Methodology

2.1 Review of energy access plans and programmes

The first stage of the project involved the review of Ghana energy access programmes since the early 1990s up to 2009. The review covered trends, plans and policies for increasing access to energy in Ghana. All documents relating to energy trends, plans and policies spanning over 50 years were reviewed with primary focus on electricity, cooking fuels and renewable energy. The review was carried out over a 4 month period, between February to May 2009.

2.2 Data collection

The collection of data formed a major aspect of the GIS-based Energy Access Project. The project anticipated this in the early stages of the project and held several meetings to discuss data collection strategies. A major outcome of these meetings was the development of a data collection framework (Table 2.1) to guide the project team in data collection. The framework was as comprehensive as possible and involved all data that the project team thought was necessary to implement the project. Even though the project team made all efforts necessary to acquire the data indicated in the framework, this was not successful as several of these data were simply not available. The majority were also in the format that made it difficult for the project team to reformat and use. The team however made the best possible use of all data acquired in achieving the objectives of the project. Later during the modelling exercise, there was the need to undertake further data collection to meet the data requirements of the model that was to be used. A new data collection framework (Table 2.2) was developed for this purpose. Again the team found it difficult to lay hands on all these data and had to make intelligent guesses based on existing practices within and outside the country. Data that could not be obtained from any of the ministries/agencies contacted and/or in any of the documents consulted included electricity demand for productive purposes, electricity demand for basic educational facilities and inter household distance for the various regions and districts in the country. It is noteworthy that in such cases where data were not available, those data were estimated with consultations with the practitioners.
### Table: Data Collection Framework

<table>
<thead>
<tr>
<th>DATA TYPE</th>
<th>SOURCE</th>
<th>DESCRIPTION</th>
<th>FORMAT</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>1.0 Base Maps</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.1 Population</td>
<td>Ghana Statistical Services (GSS).</td>
<td>District level data with projections up to the year of interest</td>
<td>preferably soft copy in excel, access, word etc</td>
</tr>
<tr>
<td>1.2 Regional/District/Province Boundaries</td>
<td>Ghana Survey Department (GSD)</td>
<td></td>
<td>preferably soft copy as shapefiles or hardcopies to be scanned</td>
</tr>
<tr>
<td>1.3 Towns</td>
<td>GSS and GSD</td>
<td>Names of Communities, their districts/provinces etc with their geolocations if possible</td>
<td>preferably soft copy in e-map, excel, access or as shapefiles</td>
</tr>
<tr>
<td>1.4 Road Network</td>
<td>GSD; Dept. of Urban and Feeder Roads; Ghana Highway Authority and Ministry of Roads and Transportation</td>
<td>Road network (rural/urban), foot paths etc</td>
<td>preferably soft copy as shapefiles</td>
</tr>
<tr>
<td>1.5 River Systems</td>
<td>GSD and Hydrological Services department (HSD)</td>
<td>Major rivers that has/can be dammed</td>
<td>preferably soft copy as shapefiles</td>
</tr>
<tr>
<td><strong>2.0 Social Services</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.1 Health</td>
<td>Ministry of Health and GSS</td>
<td>Hospitals and clinics with and without access to electricity</td>
<td>preferably soft copy in e-map, excel, access, word, shapefile etc</td>
</tr>
<tr>
<td>2.2 Education</td>
<td>Ministry of Education and GSS</td>
<td>Basic &amp; Secondary schools with and without access to electricity</td>
<td>preferably soft copy in e-map, excel, access, word, shapefile etc</td>
</tr>
<tr>
<td>2.3 Water supply</td>
<td>Ministry of Water Resources; Water Resources Commission; Community Water and Sanitation Agency and NGOs</td>
<td>Towns/communities with and without access to potable water</td>
<td>preferably soft copy in e-map, excel, access, word, shapefile etc</td>
</tr>
<tr>
<td><strong>3.0 Economic Activities</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3.1 Access to Thermal energy/mechanical power (Animal, engine)</td>
<td>Ministry of Food and Agriculture (MOFA); National Board for Small Scale Industries (NBSSI); District/ Municipal/Metropolitan</td>
<td>Towns/communities with access to thermal energy (e.g. Ovens, stoves, boilers)/mechanical power (e.g. diesel engines for</td>
<td>preferably soft copy in e-map, excel, access, word, shapefile etc</td>
</tr>
</tbody>
</table>
### 3.2 Access to irrigation facilities
- **MOFA; Irrigation Development Authority, Water Resources Commission; etc.**
- **Towns/communities with access to irrigation facilities**
  - Preferably soft copy in e-map, excel, access, word, shapefile etc

### 3.3 Enterprises with access to modern forms of energy
- **Ministry of Trade and Industry; GSS; NBSSI and Association of Ghana Industries (AGI)**
- **Rural micro and small enterprises (MSEs) with and without electricity**
  - Preferably soft copy in e-map, excel, access, word, shapefile etc

### 3.4 ICT
- **Ministry of Communication (MOC); Telecommunication service providers; National Communication Authority and NGOs**
- **Availability and powering of telecommunication systems at community levels (e.g. e-care, repeater stations)**
  - Preferably soft copy in e-map, excel, access, word, shapefiles etc

### 4.0 Access to electricity

#### 4.1 Grid, Substations
- **Ministry of Energy (MoEn); Electricity Distribution/Transmissions companies (EDTC), Energy Commissions (EC) and NSS.**
- **Network map and National level access by Communities/Households**
  - Preferably soft copy in e-map, excel, access, shapefiles etc

#### 4.2 Generators
- **EDTC; MoEn and EC**
- **Households/Towns/Communities that rely on electricity from Diesel/Petrol powered Generators**
  - Preferably soft copy in e-map, excel, access, shapefile etc

### 5.0 Access to cooking Fuels/technology
- **This excludes Electricity**

#### 5.1 Improved cook stoves
- **MoEn; UNDP; EC and GSS**
- **Number & Locations of manufacturing shops**
  - Preferably soft copy in e-map, excel, access, word, shapefile etc

#### 5.1.2 Household level access
- **MoEn; UNDP; EC and GSS**
- **Household level data**
  - Preferably soft copy in e-map, excel, access, word, shapefile etc
### 5.2 LPG

**5.2.1. Number & Location of filling stations**  
National Petroleum Authority (NPA); Environmental Protection Agency (EPA) MoEn and EC  
Number and Location of Retail Stations  
preferably soft copy in e-map, excel, access, word, shapefile etc

**5.2.2 Household level access**  
MoEn; UNDP; EC and NSS  
Households using LPG  
preferably soft copy in e-map, excel, access, word, shapefile etc

### 6.0 Renewable energy

**6.1 Solar PV**  
MoEn; EDTC and EC  
household level access  
preferably soft copy in e-map, excel, access, word, shapefile etc

- **6.1.1 Home Systems**  
  MoEn; EDTC and EC  
  household level access  
  preferably soft copy in e-map, excel, access, word, shapefile etc

- **6.1.2 Water Pumping**  
  MoEn; EDTC and EC  
  preferably soft copy in e-map, excel, access, word, shapefile etc

- **6.1.3 Other (e.g. grid connected systems)**  
  MoEn; EDTC and EC  
  preferably soft copy in e-map, excel, access, word, shapefile etc

**6.2 Solar Thermal**  
MoEn; EDTC and EC  
household level access  
preferably soft copy in e-map, excel, access, word, shapefile etc

- **6.2.1 Water heating**  
  MoEn; EDTC and EC  
  household level access  
  preferably soft copy in e-map, excel, access, word, shapefile etc

- **6.2.2. Crop drying**  
  MoEn; EDTC and EC  
  household level access  
  preferably soft copy in e-map, excel, access, word, shapefile etc

- **6.2.3. Other (e.g Solar still)**  
  MoEn; EDTC and EC  
  Household level access  
  preferably soft copy in e-map, excel, access, word, shapefile etc
<table>
<thead>
<tr>
<th><strong>6.3 Wind energy</strong></th>
<th>MoEn; EDTC and EC</th>
<th>Town/community level access (no large-scale development project is implemented)</th>
<th>preferably soft copy in e-map, excel, access, word, shapefile etc</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>6.4 Mini-hydro</strong></td>
<td>MoEn; EDTC and EC</td>
<td>Locations and number of mini-hydro plants</td>
<td>preferably soft copy in e-map, excel, access, word, shapefile</td>
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<tr>
<td><strong>6.5 Biogas</strong></td>
<td></td>
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</tr>
<tr>
<td>6.5.1 Household</td>
<td>MoEn; EDTC and EC</td>
<td>Households with access to biogas</td>
<td>preferably soft copy in e-map, excel, access, word, shapefile</td>
</tr>
<tr>
<td>6.5.2 Community</td>
<td>MoEn; EDTC and EC</td>
<td>Communities with access to biogas</td>
<td>preferably soft copy in e-map, excel, access, word, shapefile</td>
</tr>
<tr>
<td>6.5.3 Industrial</td>
<td>MoEn; EDTC and EC</td>
<td>Industries with access to biogas</td>
<td>preferably soft copy in e-map, excel, access, word, shapefile</td>
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<tr>
<td><strong>6.6 Biofuels</strong></td>
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<tr>
<td>6.6.1 Plantations</td>
<td>MoEn and EC</td>
<td>Town/community with access and possibly area of plantations</td>
<td>preferably soft copy in e-map, excel, access, word, shapefile</td>
</tr>
<tr>
<td>6.6.2 Bio-refinery/ Processing</td>
<td>MoEn and EC</td>
<td>Town/community with refinery/processing facilities</td>
<td>preferably soft copy in e-map, excel, access, word, shapefile</td>
</tr>
</tbody>
</table>
Table FEHLER! KEIN TEXT MIT ANGEGEBENER FORMATVORLAGE IM DOKUMENT..2: Data Requirements and Sources for Modelling Exercise

<table>
<thead>
<tr>
<th>SN</th>
<th>DATA CATEGORY</th>
<th>DATA REQUIRED</th>
<th>SOURCE(S)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Low voltage Lines</td>
<td>Cost per meter or kilometer of lines</td>
<td>Ministry of Energy, Electricity Company of Ghana, Northern Electricity Department</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Equipment costs (per connection)</td>
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<td></td>
<td></td>
<td>Equipment O&amp;M cost</td>
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<td></td>
<td></td>
<td>Line lifetime</td>
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<td></td>
<td></td>
<td>Line O&amp;M cost per year</td>
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<tr>
<td>2</td>
<td>Grid Extension</td>
<td>Transformer Capacities Available (kW)</td>
<td>Ministry of Energy, Electricity Company of Ghana, Northern Electricity Department</td>
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<tr>
<td></td>
<td></td>
<td>Distribution loss</td>
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<td></td>
<td></td>
<td>Installation cost per connection</td>
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<td></td>
<td>Medium Voltage Line cost per meter</td>
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<td>Medium Voltage Line lifetime</td>
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<td></td>
<td></td>
<td>Medium Voltage Lines O&amp;M costs per year</td>
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<td></td>
<td></td>
<td>Cost of transformers</td>
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<td></td>
<td></td>
<td>Transformer lifetime</td>
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</tr>
<tr>
<td></td>
<td></td>
<td>Transformer O&amp;M costs</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Diesel Generator</td>
<td>Available System Capacities (kW)</td>
<td>Mantrac; other companies</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Diesel fuel (litres) consumed per kWh</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>Diesel generator cost per kWh of energy produced</td>
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<td></td>
<td></td>
<td>Diesel generator installation cost (as fraction of generator cost)</td>
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<td>Diesel generator lifetime</td>
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<td></td>
<td></td>
<td>Diesel generator O&amp;M cost per year (as fraction of generator cost)</td>
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<td></td>
<td></td>
<td>Distribution Loss</td>
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<td></td>
<td></td>
<td>PV balance (other accessories, excluding battery) cost as fraction of panel cost</td>
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<td></td>
<td></td>
<td>PV panel lifetime</td>
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<td></td>
<td></td>
<td>PV balance (other accessories, excluding battery) life time</td>
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<td></td>
<td></td>
<td>PV battery cost per kWh</td>
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<td></td>
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<td>PV battery lifetime</td>
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<td>PV battery kWh per PV component kW</td>
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<td>PV component efficiency loss</td>
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<td></td>
<td></td>
<td>PV component O&amp;M cost per year as fraction of component cost</td>
<td></td>
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<td></td>
<td></td>
<td>PV panel cost per PV component kilowatt</td>
<td></td>
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<tr>
<td>5</td>
<td>Social, Economic and Finance metrics</td>
<td>Economic Growth Rate</td>
<td>Ghana Statistical Services; Bank of Ghana; Utilities</td>
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<tr>
<td></td>
<td></td>
<td>Population Growth Rates</td>
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<td></td>
<td></td>
<td>Electricity Demand Growth</td>
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<td></td>
<td>Elasticity of Electricity Demand</td>
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<tr>
<td></td>
<td></td>
<td>Interest Rate</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Electricity demand and/or consumption data (in kW and kWh)</td>
<td>Residential</td>
<td>Electricity Company of Ghana, Northern Electricity Department, Electricity Department, Ministry of Energy, Energy Commission</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Social infrastructure (schools, health facilities, government offices, etc)</td>
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<td></td>
<td></td>
<td>Commercial and industry</td>
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<td></td>
<td>Public uses (such as street lighting)</td>
<td></td>
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<tr>
<td>7</td>
<td>Price/cost data for both Grid and off-grid (solar, diesel) technologies</td>
<td>Materials for grid extension (poles, wire, transformers, etc.),</td>
<td>Electricity Company of Ghana, Northern Electricity Department, Ministry of Energy, Energy Commission</td>
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<td></td>
<td></td>
<td>and for off-grid (solar and diesel generation equipment)</td>
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<td></td>
<td></td>
<td>Recurring costs (operations &amp; maintenance), and “soft costs” such as</td>
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<td></td>
<td></td>
<td>system design and installation</td>
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<tr>
<td></td>
<td></td>
<td>Electricity connection fees for households, businesses (single-phase and</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>three-phase)</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>Geo-spatial location data</td>
<td>Coordinates of Communities and locations of existing grid networks plus</td>
<td>Ghana Statistical Services, Ministry of Energy, Utilities</td>
</tr>
<tr>
<td></td>
<td></td>
<td>the population data for those communities.</td>
<td></td>
</tr>
</tbody>
</table>
2.3 Development of GIS e-Maps

The base maps used in the project were created using the ArcGIS software. Base maps were obtained from the Survey Department of Ghana and the “Ghana- Country at a Glance” dataset. This included the following:

- Regional and District boundaries
- Road network
- Rail network
- Forest Reserves
- Rivers and other water bodies
- Towns
- 1:50000 digital Ghana topographic maps

Due to the unavailability of comprehensive town maps, new maps were created from the topographic maps obtained from the Survey Department.

Map for Social Services/amenities were prepared using the base maps that had been prepared. The attribute information for these social services were obtained from the Ministry of Energy, Energy Commission, Ministry of Health, Ministry of Education, Ghana Water Company Limited and the Community Water and Sanitation Agency of Ghana. The maps prepared include the following:

- Map showing locations of Electricity Company of Ghana substations
- Map showing electrification status of communities in the country
- Map showing locations of potential mini-hydro dams
- Map showing wind regimes across the country
- Map showing solar radiation
- Map of basic schools with & without access to electricity
- Map of communities with clinics and hospitals and their electrification status by district and region
- Map of communities with access to biogas
- Maps showing locations of LPG stations in Ghana
- Map showing population distribution across the regions and districts

For the ‘social service’ maps, such as basic schools and hospitals with and without access to electricity, the project team could not obtain a comprehensive community map as these maps were not available. The locations of towns were therefore represented by their names as text with no points defining them. To get the points to represent the towns, the texts (names) on the tiles were converted to points using the midpoint option. The towns were mapped from a 1 in 50000 topographic maps which was the highest resolution available at the time of carrying out the assignment.
2.4 Preparation of methods and tools for energy planning

2.4.1 Modelling using network planner

Energy agencies spend more time and resources to undertake studies to obtain reasonably accurate estimates of electrification cost for communities. Therefore, there is the need for planners to develop tools to make rapid assessment of cost-effectiveness of grid expansion and other decentralised technology options (Solar Photovoltaic (PV), Diesel mini-grid) for electrifying communities. A model adopted in this project (called the Network Planner) is a decision support tool for exploring different electrification technology options in un-electrified communities. This model is a python-written language program developed by a team from Modi Research Group, the Earth Institute at Columbia University, based in New York, USA. The model combines data on electricity demands and costs with variability in population density and other socio-economic data to compute detailed projection costs of three electrification options and propose the optimal cost-effective option for electrifying a community within a specified time horizon. This helps planners to prioritize areas where grid expansion is a cost-optimized option and where other decentralised options provide the cost-optimized options of electrification for any un-electrified community within a specified time horizon. The three electrification technology options considered include: (i) Off-Grid (solar PV panel supported by small diesel generator for production use), (ii) Mini-Grid (solely on diesel generator) and (iii) Grid electrification (internal grid plus external connection to the existing grid network).

The model incorporate geographical information system (GIS) tool to perform spatial processing and analyses, using simple geospatial and population data, and algorithmically generates a comprehensive, cost-optimized electricity plan, including a map of the projected grid extension, communities to be served by off-grid technologies, and all related costs. The model generates results at any geographical scale (National, regional or local level) based on the availability of data used in the modelling. The result provides policy-makers a tool for planning electrification expansion at any scale, either at national or local levels. The output model results can be visualized on a map to show the communities with their proposed targeted electrification; existing and proposed grid network linking the communities. Since electricity demands of the various sectors are spatially distributed, there is the need to spatially model such demands. Fortunately, this model seeks to address this option.

Another important usage of the model is its ability to perform sensitivity analysis. The model is a scenario-based model that helps planners to understand the effects on electrification cost by changing certain factors due to the inherent uncertainties in these factors such as demands, prices and policies. For instances, what will be the effect of changing the cost of diesel fuel? What will be the effect if the cost of solar PV is reduced since the government has a policy of promoting solar PV? What will be the effect of changing the penetration rate for household connections? All these questions and others can be answered by the model. The main aim of this modelling exercise is to estimate a cost-optimize approach of
expanding electrification to un-electrified communities to help policy makers and private investors in planning their investment needs.

2.4.2 The concepts of the model

Data requirement

The data used for modelling the un-electrified communities are grouped into five (5) categories:

1. Geospatial data - the spatial location of the un-electrified communities and the existing grid network which are needed by the model to compute distances, and therefore costs, to connect communities with MV line;
2. Socio-economic data – data on interest rate, economic growth rate and elasticity of electricity demand per year which are needed in estimating the discounted cost and projecting cost in a specified time horizon;
3. Demographic data - initial population, population growth rate, and mean household sizes which are needed to project population and household count to the base year, and to project electricity demand at the end of the time horizon;
4. Electricity demand – including four facility demand types: household, productive (such as grinding mills, water pumps, welding shops), commercial (shops, market places, industries) and institutional (health, education, public lighting); and
5. Cost data – both initial and recurring costs (such as fuel, operation and maintenance) of grid electrification and the two decentralised technologies (diesel mini-grid and solar PV). It is noteworthy that beside these above-mentioned options, any other decentralised technology options such as wind technology can be used. This project used the two above-mentioned decentralised electrification options because of the availability of cost and technical data, wide geographic applicability, and the acceptability to communities.

Modelling projected population and its demand data

The growth of electricity demand of a location is dependent on its economic and population growth, as well as a settlement’s total population higher economic and population growth rates have higher electricity demands, and settlements with larger total populations (towns and cities) tending to have higher electricity demand per household than small villages.. In the initial step, the user loads data into the model, including the geospatial data (latitude and longitude coordinates) of the communities and the base year population of each. The model then applied different population growth rates to rural and urban areas based on the user-defined urban threshold (a value of population size below which a community is deemed rural and above which is deemed urban) in projecting the population to the final year of the planning time horizon. The model applied the population growth rate every subsequent year till the planning year, including provisions allowing for a rural community to
begin with rural growth and end up with urban growth rate as its population passes the urban-rural threshold.

Combination of population growth rate (rural and urban), mean household size, economic growth rate, peak demand data and the base year electricity unit demands of the communities are used to project the total electricity demands needed at the end of the specified time horizon.

Table: Regional Population Data and Their Population Densities

<table>
<thead>
<tr>
<th>Region</th>
<th>Estimated 2010 Population</th>
<th>Land Area (km²)</th>
<th>Population Density (Persons/km²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ashanti</td>
<td>4,725,046</td>
<td>24,389</td>
<td>197</td>
</tr>
<tr>
<td>Brong Ahafo</td>
<td>2,282,128</td>
<td>39,557</td>
<td>57</td>
</tr>
<tr>
<td>Central</td>
<td>2,107,209</td>
<td>9,826</td>
<td>211</td>
</tr>
<tr>
<td>Eastern</td>
<td>2,596,013</td>
<td>19,323</td>
<td>137</td>
</tr>
<tr>
<td>Greater Accra</td>
<td>3,909,764</td>
<td>3,245</td>
<td>1,303</td>
</tr>
<tr>
<td>Northern</td>
<td>2,468,557</td>
<td>70,384</td>
<td>35</td>
</tr>
<tr>
<td>Upper East</td>
<td>1,031,478</td>
<td>8,842</td>
<td>115</td>
</tr>
<tr>
<td>Upper West</td>
<td>677,763</td>
<td>18,476</td>
<td>38</td>
</tr>
<tr>
<td>Volta</td>
<td>2,099,876</td>
<td>20,570</td>
<td>100</td>
</tr>
<tr>
<td>Western</td>
<td>2,325,597</td>
<td>23,921</td>
<td>97</td>
</tr>
<tr>
<td>High</td>
<td>4,725,046</td>
<td>70,000</td>
<td>1,303</td>
</tr>
<tr>
<td>Average</td>
<td>2,422,343</td>
<td>23,800</td>
<td>229</td>
</tr>
<tr>
<td>Low</td>
<td>677,763</td>
<td>3,000</td>
<td>35</td>
</tr>
</tbody>
</table>

The model employs two kinds of user-defined curves to model the variation across settlements of different size in both the number of electricity demand points per settlement, and the magnitude of electricity demand at those points. The first is the “facility count curve,” which plots the number of facilities of a given type (schools, clinics, commercial facilities) against the population of the settlement that contains those facilities at the starting time point. This creates a logistic curve, which quantitatively expresses the tendency for larger settlements to have more facilities of various types (i.e., cities have more schools and clinics than villages). The second is the “logistic demand curve,” which plots the variation in electricity demand for various points or structures (households, facilities) against changing settlement population. This creates another logistic curve, which expresses the tendency for homes and facilities in larger settlements to have higher electricity demand than homes or facilities in villages (i.e. hospitals demand more power than rural clinics; urban homes typically use more electricity on average than homes in the smallest villages).
Both curves employ data from the model’s starting year to create a logistic curve that can be used to predict a quantity – either number of facilities, or electricity demand for a given demand point – in the final year, based upon the predicted population of a settlement. These curves are based on empirical data obtained from the relevant energy agencies and thus are an important aspect of localizing the model.

Modelling cost data for each technology
The model requires detailed cost components of the three electrification technologies such as the cost of medium voltage (MV) lines, low voltage (LV) lines, transformers, diesel generators, diesel fuel per litre, solar panels and solar batteries, as well as recurring costs, including operation and maintenance. Moreover, the model requires interest rate per year to be used to determine the discounted costs for each technology option which will be combined with other cost components in estimating the projected cost of electrification for each technology option based on the projected electricity demands at the end of the planning time horizon.

Selecting the least-cost technology option
In proposing the optimal-cost technology option for un-electrified communities, the model first computes the total costs of electrification, including all initial and recurring costs, for the three different electrification technology options based on the projected electricity demands of the communities for a specified time horizon. These three potential electrification options include: (i) Off-Grid – defined as solar photovoltaic (PV) electricity for households supplemented by a diesel generator for productive use (ii) Mini-Grid defined as diesel generator power with low voltage (LV) distribution for all demands type (household, productive, social infrastructure, etc.) and (iii) Grid Electrification – This electrification technology consists of two grid connections: “internal” and “external”. The “internal” grid connection refers to cost for the secondary MV lines, LV-lines, transformers and internal house wiring needed to connect households, commercial structures and various institutions within a community. The “external” grid connection refers to extension of MV-lines from a transformer in the community to the nearest point of the MV grid network.
Thereafter, the model compares the discounted costs of the two decentralised, or “stand-alone” options (Off-Grid and Mini-Grid), and selects the one with the lowest cost. The discounted cost of this least-cost standalone option is then compared with the discounted cost of only the internal component of grid connection costs for a community. If the least cost stand-alone option is lower in cost than the internal grid cost, this indicates that grid connection is not a viable option for the community, and the model designates the least-cost stand-alone technology as the final recommended electrification option.
However, if the internal grid component is less costly than the least-cost standalone option, then the difference in these two costs represents the budget available for the external
component of the grid connection costs for such communities – namely, the MV line to connect to the nearest grid location. By dividing this value by the cost of MV-line per meter, the model obtains a key decision metric, ‘MVmax’ for each community. The MVmax, expressed in meters, represents the maximum length of MV-line which can be installed for each community before the cost of grid extension exceeds the cost of the least-cost stand-alone option. The metric is community specific and provides a simple estimate of how far the existing MV-line network can be cost-effectively extended to reach this community.

Finally, the model applies a geospatial algorithm to compare these MVmax values with the actual distances between the location of unconnected communities (identified by latitude and longitude coordinates), and identifies those sites with MVmax values that justify grid connection. Those communities that are selected, indicating that grid extension is the most cost-effective technology to electrify a community, are recommended for grid connection by the model; in other words, they are ‘grid-compatible’. Those communities beyond the MVmax values are instead recommended for electrification using the least-cost stand-alone option.

2.4.3 Limitations of the model

Though, the model has been proven to provide an effective tool for national electrification planning, the following listed limitations should be pointed out:

- The model connects communities to the grid in straight lines ignoring most geographical and technical constraints. The capital cost may be increase if these constraints – and particularly the need for the grid to follow major roads – are considered.
- The cost assumptions used in the models reflect the best available data. However, costs are constantly changing due to technological and economic factors and the model assumes that the conditions will remain the same for the time horizon specified which in reality might not be the case.

2.4.4 Development of GIS-based Energy Access Review (GEAR) Toolkit

The main aim of this part of the project was to develop software which will serve as a tool to manage the energy access data of Ghana, including results obtained from the modelling exercise. The production of a digital map and a functional geo-database of the facilities assist in the adequate distribution of energy in the following areas:

- Creation of a geo-database (spatial/attribute) for the features for updating, based on their conditions.
- Capturing of the geometric and attribute data of electrified and un-electrified communities etc.
- Update and modification of information concerning facilities for electricity distribution such as electrified and non-electrified communities in Ghana, etc.
Faster and easier retrieval of information for instantaneous use in the area of planning, managing and monitoring of electrified communities and the trend of LPG access in communities.

Performing spatial analysis on Energy Information.

The development of the GIS-based Energy Access Review (GEAR) Toolkit also involved the following stages. A flow diagram showing the methods employed in developing the toolkit is shown in Figure 2.1.

**Figure 1**: Model Flow Diagram Showing Methods Employed
The preparation of the datasets for the GEAR Toolkit involved the identification of relevant data to fulfil the objectives of the project. As a result, the following activities were carried out:

i. Specification of the database contents and structure, identification of hardware and software configuration for data capture, and output devices as well as data processing and storage.

ii. Selecting suitable spatial or graphic documents and their attributes.

iii. The following factors were considered during digitizing:
   - Coordinate system to be used
   - Accuracy of the layers as well as that of the map
   - Consistency in data entry
   - Reference points to be chosen to coincide on all connecting sheets

Editing is important in order to minimize if not remove completely the number of digitizing errors such as missing lines and polygon and, distorted lines or topology of related polygons such as dangling arcs and unclosed polygons. The following stages were followed in editing the digitized map features in ArcMap.

- **Choosing the workspace and data frame to be edited:** The data frame view provided the principal display of geographic information as a series of map layers (Figure 2.2). This also came with a geographic extent and a map projection for displaying geographic features. The data frame has a set of spatial properties that allow users to interact with it. These included the name of the data frame, a display coordinate system or map projection through which the layers were displayed in a common view, a size and position that locates the data frame onto map page and text labelling properties for the map layers in the data frame.

- **Choosing edit tasks:** This refers to editing operations that can be performed on features. These features were grouped into their general functions namely create data, modify data and work with topology.

- **The next step was choosing a tool and creating an edit sketch.** To create or modify the shape of features, a temporary representation of that feature called edit sketch was used. The sketch tool and the tools on the editor toolbar palette were used to create and edit the layers. Arc Map allows the user to choose between creating new features and editing existing new ones. In editing features, *edit existing ones* tab was mostly used in editing. Sketches were used to modify existing features such as re-shaping polygons, trimming and extending lines and splitting lines and polygons.
In Arc Map, new attribute values can be entered when new features are created and existing values can also be edited. During spatial data entry, default attribute values including automatically generated ID were observed. The attributes entered in the various columns included names of regions, districts, communities in addition to their respective population sizes, electricity and LPG access rates and characteristics.

There are two main methods of editing or updating attributes in ArcMap: Attribute Dialogue Box and the Table Window. The attributes dialogue box shows attributes of selected features, and displays the raw data and fields as they are stored in the database. The table window can also be opened to see all the tabulated information about a layer. The table window was mostly used to enter data since it is user-friendly. Map text known as annotation was created in the geo-database. Because annotation can select individual pieces of text and edit them, it provides flexibility in the display and positions of the text. Similar processes adopted in editing other features were followed using specialized annotation tools during creation and editing of annotations. After every edit session, edits are temporarily saved until they are saved by the user and applied permanently to the data.

### 2.5 Management arrangements

The Ghana Ministry of Energy, the Ghana Energy Commission together with ECOWAS, UNDP and EUEI-PDF and The Energy Centre, KNUST formed a steering committee for this project.
and met twice in the course of the project to review the advancement of the project and discuss/validate project documents. Meetings of the Steering Committee were held back-to-back with other meetings/workshops whenever practicable to avoid major travel-related expenditures. The project team headed by the Project Coordinator was in charge of the preparation of quarterly progress reports including the final report of the project achievements. Major meetings and workshops held and dates they were held are presented in Table 2.4. There were other minor meetings at various locations in Ghana during the data collection phase. The project team also met on numerous occasions during the project implementation period. Details of the meetings held in 2011 are presented in section 7 of the report.

**Table FEHLER! KEIN TEXT MIT ANGEGEBENER FORMATVORLAGE IM DOKUMENT..4: Major Meetings and Workshops Held During Project Implementation**

<table>
<thead>
<tr>
<th>Meeting/Workshop</th>
<th>Date held</th>
<th>Venue</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ghana Energy Access Review (GEAR) Roundtable</td>
<td>4 June 2009</td>
<td>The Energy Center, KNUST</td>
</tr>
<tr>
<td>First Steering Committee Meeting</td>
<td>5 June 2009</td>
<td>The Energy Center, KNUST</td>
</tr>
<tr>
<td>Off-site Project Team Meetings</td>
<td>3-4 September 2009</td>
<td>Ejisu, Ghana</td>
</tr>
<tr>
<td>Familiarization Meeting with Senegalese Team</td>
<td>16-24 January 2010</td>
<td>Dakar, Senegal</td>
</tr>
<tr>
<td>Familiarization Meeting with Burkinabe Team</td>
<td>29 March – 1 April 2010</td>
<td>Ouagadougou, Burkina Faso</td>
</tr>
<tr>
<td>Stakeholder Meeting</td>
<td>2-3 June 2011</td>
<td>The Energy Center, KNUST</td>
</tr>
<tr>
<td>Sensitization of District Planning Officers</td>
<td>9 June 2011</td>
<td>The Energy Center, KNUST</td>
</tr>
<tr>
<td>Last Steering Committee Meeting</td>
<td>10 June 2011</td>
<td>The Energy Center, KNUST</td>
</tr>
<tr>
<td>ECOWAS Meeting, Multisectoral Group on Energy Access</td>
<td>21-23 July</td>
<td>Bamako, Mali</td>
</tr>
<tr>
<td>(Project team presented project results at the meeting)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Training Session for Energy Commission and Allied Agencies</td>
<td>3-4 August 2011</td>
<td>Accra, Ghana</td>
</tr>
<tr>
<td>Training Session for ECOWAS/ECREEE</td>
<td>22-26 August 2011</td>
<td>The Energy Center, KNUST</td>
</tr>
<tr>
<td>Off-site Project Team Meeting</td>
<td>16 September 2011</td>
<td>Ejisu, Ghana</td>
</tr>
</tbody>
</table>

The remaining chapters of this report present the outcome of the project/ project results with each major activity featuring as a separate chapter. The conclusions and recommendation immediately follow the project results and is presented as the last chapter of this report.
3 Review of Ghana’s Energy Trends, Policies and Plans

The intent of the energy policy review was to assess the trends, policies, plans and programmes developed over the years to ensure increased access to energy services in Ghana by 2020 and beyond. The review was undertaken as a key component of the GIS-based Energy Access Project to complement existing policies, plans and recommendations from the Energy for Poverty Reduction Action Plan for Ghana (EPRAP) and the Ghana Energy Development and Access Project (GEDAP) to spur national and regional energy access targets and thus to expedite the achievement of MDGs and ECOWAS White Paper on access to energy services. The review thus unveils the phenomenal contribution of energy to the socio-economic development of a country and relays that to usher Ghana into a vibrant economic status, increased access to modern energy (electricity, Liquefied Petroleum Gas, etc.) decidedly constitutes an important driver. Energy access definition here is restricted to community access (which is the Ghana Ministry of Energy definition) instead of the household, although reference is be made to the latter where appropriate.

3.1 Ghana’s strategic energy plans and targets

The drive for energy plans/policies in Ghana dates back to 1985 with the preparation of a project by the Volta River Authority to extend the 161 kV National Grid to the northern part of Ghana to connect all the administrative regions of Ghana under the Northern Electrification and System Reinforcement Project (NESRP). The NESRP led to the initiative for the National Electrification Scheme (NES) which was expected to increase electrification in the country between 1990 and 2020. The NES aimed at providing within a 30-year time frame, electricity access to all settlements with population exceeding 500. The NES was pursued through various discrete projects prominent among which were the Northern Electrification Project and the Self-Help Electrification Project (SHEP).

The SHEP was a nation-wide scheme that was introduced as a policy framework under which communities could advance their electrification projects ahead of the dates indicated in the NES by meeting agreed criteria for community contributions to the project implementation. In other words, the intent of the SHEP was to expedite rural electrification which was part of a broader National Electrification Scheme. Apart from the government’s obligation to provide the conductors, transformers, pole-top and other materials and assume responsibility for the construction works required for the connection, the following three pre-requisites must be satisfied, for communities to qualify under the SHEP. The beneficiary communities should:

1. Be within 20km radius of an existing 33kV or 11kV electricity grid network.
2. Be willing to provide their own Low Voltage (LV) poles to connect to the existing network.
3. Have one-third of households (houses) already wired.

Interestingly, as communities qualified under the SHEP, adjacent non-electrified communities intuitively met one of the pre-requisites and thus increased the possibility of
electricity network (not qualified under SHEP), once adjacent communities within 20km were electrified, the communities which were previously not qualified may meet the existing grid network criterion because it will be 10km farther away from the grid.

As the aforementioned projects were being implemented, government came up with some plans to boost the process towards achieving universal access to modern energy. Notable among these plans were the Energy for Poverty Reduction Action Plan (EPRAP) and the Strategic National Energy Plan (SNEP) both prepared in 2006. The SNEP has strategic targets for both the energy demand sector and the supply sector whereas EPRAP has targets for the demand sector. In the supply sector, the SNEP targets are further disaggregated into residential sector, commercial and service sector, agricultural and fisheries sector, transport sector and industrial sector.

In the residential sector, the plan is:

- To achieve 100% access to electrification by 2020 and in the process achieve 15% penetration of rural electrification by decentralized renewable energy complementation by 2015 expanding to 30% by 2020.
- To reduce the average woodfuel energy intensity per urban household by 30% by 2015 and by 50% by 2020.

The plan for the commercial and service sector is:

- To achieve 1% penetration of solar energy in hotels, restaurants and institutional kitchens using solar water heaters by 2015 and 5% penetration by 2020.
- To increase LPG penetration to 20% by 2015 and 30% by 2020.
- To achieve 1% penetration for biogas for cooking in hotels, restaurants, and institutional kitchens by 2015 and 2% by 2020.

In the agricultural and fisheries sector, the SNEP aims to:

- Achieve 2% penetration of biodiesel by 2015 and 10% by 2020.
- Achieve 20% penetration of solar energy by 2020.
- Increase electricity penetration to 2% by 2015 and 5% by 2020.

The projections are aimed at propelling Ghana’s desire to achieve a US$ 1000 per capita by 2015 and subsequently maintain a middle-income status up to 2020 which are tailored to the targets set by government for improvement in other sectors.

In addition, the goal of EPRAP was to provide a ‘roadmap’ for the targeted delivery of energy services to support the realization of national development/poverty reduction goals and strategies outlined for the implementation of seven key areas under the GPRS II. The seven sectors are Agriculture, Small and Medium Enterprises, Health, Education, Water and Sanitation, Communication and Technology, and Household. The broad objectives of the Plan of Action proposed in EPRAP are as follows:

- Facilitate the provision of reliable electricity to support and enhance the delivery of essential social services such as education, health care and potable water as well as the deployment of Information and Communication Technologies (ICTs) in rural areas
Facilitate the provision and use of modern energy services (in the form of mechanical and/or electrical power) at the community level for all rural communities for productive applications.

Facilitate the provision and use of affordable modern cooking fuels and devices to at least 50% of households currently using traditional biomass for cooking.

The current energy targets of Ghana are:
1. Achievement of universal electrification by 2010 and
2. 50% access to LPG by 2015.

### 3.2 Trends in electricity access

In terms of access to electricity, Ghana has made a big leap forward over the years between 1990 and 2010. Electricity access rates in Ghana increased from an average of 28% in 1990, 29.5% in 1990/92, 41.4% in 1998/99, 43.7% in 2000, 50.6% in 2003, 49.2% in 2005/6 and eventually rose up to 66.7% in 2009. Current estimates provided by the Ministry of Energy place Ghana’s electricity access rate at about 72% in mid-2010 (see Figure 3.1). There has also been corresponding increases in electricity access at the regional levels with the Greater Accra region and Ashanti region recording the highest access rates of 96% and 81% respectively in 2009 (Ministry of Energy, 2009). Access rates in the two leading regions have increased to 96.8% (Accra) and 84.1% (Ashanti region) in mid-2010. Similar increases in access rates have been recorded in the Northern region from 43.60% in 2009 to 50.1% in mid-2010, Upper West (from 31.95% in 2009 to 39.9% in the mid 2010), Upper East (30.43% in 2009 to 43.6% in mid-2010). Whilst national electricity access is very cheering, there is a marked disparity in the household access between urban and rural areas as the former is close to than twice that of the latter.

The increased access rates are accompanied by corresponding increases in energy consumption in the country at the household, industry and commercial levels. It is estimated that, household electricity consumption increased from 1,585 GWh (26% of national consumption) to 1,957 GWh (37%) in 2005 and further increased to 2,095 GWh (38%) in 2007. Such phenomenal increases show promising efforts to address the eight objectives set by the MDGs. However, not until such electricity is increasingly used for delicate sectors of the economy such as industries, health, agriculture and education, the high electricity access rates would not yield the expected or corresponding gains to address the MDGs.
3.3 Trends in access to modern cooking fuels

In Ghana LPG is used as a fuel for cooking and transport. In 1990, the Government of Ghana launched a National LPG Programme under which the Tema Oil Refinery was to be modernized and a massive LPG campaign implemented. This offered the opportunity to promote LPG as an alternative energy to charcoal and firewood. The promotion targeted urban households, public institutions requiring mass catering facilities and the informal commercial sector including small-scale food sellers. Government’s initiative were fruitful since the consumption of LPG doubled in 1992, and by 2004 domestic consumption was over 60,000 tonnes/year which was estimated to be about ten times higher than the quantities consumed before the promotional programme was launched. Though the LPG drive was successful, it is observed that patronage was skewed in favour of urban dwellers. Out of the 6% of households in 2004, and about 9% in 2005 using LPG as their primary source of fuel for cooking, 70% resided in Greater Accra and Ashanti regions. In Accra, the nation’s capital, about 22.7% in 2004 and about 30.4% in 2005 of households used LPG. Urban access to LPG was estimated to be 17.2% and in contrast, LPG in rural areas accounted for about 1.2% of total national consumption. A recent study found that only about 19% of households in the upper income quintile in Ghana have access to LPG, reducing to about 2% in the lowest income quintile group. As of December 2003, there were 98 LPG filling stations in Ghana, 64 of which were situated in the Greater Accra region and only one station each in the Upper East and Upper West regions. In 2004, the Government with financial support from the United Nations Development Programme (UNDP) under its
Rural LPG Challenge programme re-launched the LPG campaign programme to focus on the Northern regions of Ghana. A national survey conducted by the authors in early 2011 indicates that there are currently more than 250 LPG filling stations in the country as shown in Figure 3.2.

![Figure 3.2: Evolution of LPG stations in Ghana](image)

3.4 Trends in access to renewable energy

3.4.1 Woodfuel

The country’s renewable energy resources that have been extensively studied as potential sources for energy production and utilization are bioenergy (particularly, solid biomass and biogas), solar, wind and small hydro.

Ghana’s Energy Commission reports that firewood and charcoal contributes about 63% of the total energy supplied to the consumer compared to 27% for petroleum products, and 9% for electricity. A breakdown of the national energy balance data reveals that the residential sector of the country consumes the largest share of the energy supply due to the high reliance on woodfuel to meet mostly domestic needs. It has also been reported that the consumption of woodfuel increased by 58% between 2004 and 2008, while the consumption of charcoal also increased by about 50% during the same period.

In order to reduce the consumption of woodfuels and to reduce in-door air pollution in cooking places, there have been some efforts toward disseminating improved cookstoves in the country. Among the prominent cookstoves that have been introduced in Ghana are the Ahibenso and the Gyapa. The Ahibenso stove, which could save about 18.4% on charcoal consumption compared to the traditional stove, was introduced in the early 1990s and some
40,000 stoves had been sold out by 1993. Current data on access and impacts are not available and the stove is not very popular in the country these days as compared to Gyapa. Gyapa stove was introduced in 2002 by Enterprise works and over 200,000 had been sold by 2006 through a vigorous marketing campaign. The Gyapa stove has remained popular with Ghanaians and still continues to sell in various towns across the country.

3.4.2 Solar energy

Ghana receives on average 4.0-6.5 kWh/m²/day of solar radiation and sunshine duration of about 1800-3000 hours per year. Over the years, solar PV systems have attracted considerable attention and excitement, particularly in situations of energy crisis. In Ghana, solar PV is making contributions to electricity access for household lighting, communication, water pumping and rural vaccine storage. Public solar PV electrification projects were first implemented in the early 1990’s. By December 2003 about 4,911 PV systems were installed with total installed power of 1.0 peak megawatt (MWp) as shown in Figure 3.3. Data from the Ministry of Energy and other reliable sources are not available from the years 2004 to date. However, Ghana Statistical Service reported 0.2% as the contribution of solar energy to the total energy supply in terms of the population using solar for lighting.

![Figure](image.png)

**Figure** Historical evolution of solar photovoltaic installations in Ghana

3.4.3 Wind energy

Over the past 20 years extensive assessment of wind energy potential in Ghana has been carried out and reliable data on wind is available for Ghana. Indications are that the coastal belt of Ghana is endowed with good wind energy potential. Wind measurements taken at 12 metre height along the coast revealed wind speeds varying from 3.33 m/s to about 6.08 m/s. However, practically, the most economic exploitation based on current technology is at 50
metre-height with annual average wind speed ranging between 7.1 and 9.0 m/s, classified as “Moderate” to Excellent.

The lower wind speeds nearer ground level are suitable for energy conversion devices like wind-powered water pumping systems. Though some wind energy systems have been spotted in the country, there is no data on energy supply from such wind systems in Ghana and little research has been done on the potential contribution of wind energy, especially in distributed non-grid systems, towards the goal of increasing energy access for all by the year 2020.

3.4.4 Small hydro

Over seventy (70) small hydro sites have been identified in Ghana but none of these has been developed so far. It has been estimated that Ghana’s small hydro potential could be put at 1.2-4 MW if the potential sites are developed as simple run-of-river projects, sized to provide power to rural communities not connected to the national grid, and at 4-14 MW if the plants are connected to the national electrical grid to absorb the excess energy output. It has been recommended that, especially for the low height sites in the Volta Region, serious consideration should be given in future to the development of integrated power and irrigation infrastructure to include small hydro plant providing power to pump the water to farms and supply the excess energy to the national grid.
4 Assessment of Energy Needs and Comparison with ECOWAS Targets and MDGs

4.1 ECOWAS Targets and MDGs on Energy Access

The ECOWAS White Paper on Access to Energy Services for Rural and Peri-Urban Populations is a regional strategy that seeks to support economic growth through the provision of energy services for citizens of the region. It is partly funded by United Nations Development Programme (UNDP) and the European Union Energy Initiative Partnership Dialogue Facility (EUEI-PDF). The plan which was set up in 2005 was a follow-up of regional targets and objectives set by the New Partnership for Africa’s Development (NEPAD) including increasing access to reliable and affordable commercial energy supply by Africa’s population in 20 years with emphasis on productive activities for economic growth and reversing environmental degradation associated with traditional fuels. In the White Paper, ECOWAS has proposed specific targets for increasing access to modern energy services (Table 4.1) in member countries.

<table>
<thead>
<tr>
<th>Energy Service</th>
<th>Target</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modern energy for cooking</td>
<td>100%</td>
</tr>
<tr>
<td>Modern energy services/electricity for basic needs in urban and peri-urban areas</td>
<td>100 %</td>
</tr>
<tr>
<td>Electricity for rural households</td>
<td>36%</td>
</tr>
<tr>
<td>Electricity for schools, clinics and community centres</td>
<td>60%</td>
</tr>
<tr>
<td>Mechanical power for productive uses in rural areas</td>
<td>60%</td>
</tr>
</tbody>
</table>

The Millennium Development Goals are the world’s time-bound and quantified targets for addressing extreme poverty, in its many dimensions including income, poverty, hunger, disease and lack of adequate shelter while promoting gender equality, education, and environmental sustainability. A common mental projection made given the aforementioned sets of conditions is: ‘how will the world look in 2015?’. Despite the eight major issues that the MDGs seek to address, energy poverty which is prominent in deprived rural and urban households in developing countries is missing. But it is evident that health promotion, agricultural and educational improvement as well as environmental sustainability cannot be achieved without energy. The United Nation’s Millennium Project therefore recognises the role of energy services especially modern cooking fuels as a prerequisite for development and thus seeks to energize MDGs. For countries to achieve MDGs, the following energy
targets are recommended: (i) to reduce the number of people without effective access to modern cooking fuels by 50% by 2015 and (ii) and make improved cooking stoves widely available.

### 4.2 Ghana’s Energy situation in relation to ECOWAS and MDG targets

A comparative analysis of the country’s electricity access with ECOWAS targets reveals that, Ghana has made significant strides. As of mid-2010, Ghana had surpassed the ECOWAS rural electricity targets of 36% access and is close to achieving the 100% urban access by 2015 (see Figure 4.1). More so, Ghana is placed second to only Cape Verde in terms of electricity access and ranked higher than Nigeria, Cote d’Ivoire and Senegal given an estimated electricity access rate of 72% (percent of population) in 2010 (see Figure 4.2). However, Ghana’s impressive electricity access rates has not translated into increased access to modern fuels for cooking and heating as countries like Cape Verde and Senegal. Access rates available for 2008 and shown in Figure 4.3 indicates that access to modern fuels in Ghana was only 12% as compared to Senegal’s 41% and Cape Verde’s 63%. Ghana’s current access rate to modern fuels means that it is not likely that the country will be able to achieve the ECOWAS target of 100% by 2015. The implication is that, the use of unclean energy sources (wood fuel and charcoal) and their dire consequences will continue to make a large proportion of the population vulnerable to numerous health risks and the consequent effects of derailing the achievement of MDGs.

![Graph comparing Ghana’s electricity access rate with ECOWAS achievements](image)
Figure: Electricity access rate in ECOWAS countries, 2005 and 2010

 Targets for Electricity
 ECOWAS (average): 50% by 2015
 Ghana: 100% by 2020

 Targets for Cooking Fuels
 ECOWAS, Modern Energy: 100% by 2015
 Ghana, LPG: 50% by 2015
4.3 Existing gaps in Ghana’s energy access

Having compared Ghana’s energy access with the ECOWAS targets and MDGs, this section provides the energy gaps and policies to be designed to address them to drive the economy. Millennium Development Goals emphasize not only poverty reduction in terms of income but also highlight the importance of improved health, universal primary education, women’s empowerment and gender equality. In other words, without the provision of regular, efficient and cheaper energy services, achieving MDGs will be a difficult task. The Millennium Project is explicit in its assertion that modern energy services help drive economic growth by improving productivity and enabling local income generation through improved agricultural development and non-farm employment. It further opines that, if made available to all income groups, modern energy services become an invaluable means of improving social quality. Modern energy services are thus decidedly needed to alleviate poverty, reduce hunger, raise educational and health standards in developing countries.

However, there are lots of gaps in Ghana’s energy discourse. A major gap in Ghana’s energy access at the household level is that, lighting and television alone is said to account for 80% of rural electrification consumption and this forms a bulk of the benefits delivered by electrification. Moreover, virtually 100% of households with electricity are geared towards lighting (Barnes, 2007). The widespread use of electricity almost entirely for lighting (limited use for cooking) in households, and the high electricity tariffs for non-residential activities raise questions or uncertainties with regards to achieving MDGs especially in the deprived rural areas. The high costs of electricity tariffs for non-residential sectors discourages the use of electricity for productive activities (SMEs) which is intended to contribute to income generation and employment creation in lagging communities.

In addition, more than 50% of the population not having access to electricity in Ghana lives in settlements smaller than 500 by 2020. With the country’s plan to electrify settlements above 500, it has been espoused by some energy experts that a large part of the country’s population (~15%) will remain un-electrified by the 2020 timeline. This presupposes that universal electrification by 2020 policy which has rekindled by the government is implausible if the status quo is maintained as about 85% of the population will be electrified. Nonetheless, the aforementioned guiding principle of the NES/Universal electrification by 2020 is seldom followed in practice because many smaller communities with population smaller than 500 are electrified in the course of electricity grid extension programmes. This has been possible on the grounds of ethics as well as the need to satisfy such small communities lying in between bigger settlements ready for electrification in order to avoid conflicts. Moreover, there are some communities with population smaller than 500 which
are electrified under GEDAP and SHEP. These issues highlighted are research gaps in Ghana’s energy access that needs to be addressed in the near future.

Furthermore, due to the popular lack of interest in off-grid electrification options (Solar PV systems or Diesel-mini grid power generation) in smaller/rural communities, the non-existence of grid electrification to such a large proportion of the country’s population will defeat the purpose of rural electrification, which is primarily intended for income generation and employment creation for poverty alleviation.

Addressing MDGs through access to modern cooking fuel (especially LPG) for cooking energy access also remain a serious development challenge. The health advantages associated with modern cooking fuels are lower smoke exposures, improved ventilation of cooking areas with its consequent effect of reducing the disease burden resulting from smoke, lower child mortality rates, and improve maternal health. Beside the limited use of electricity for cooking at the household level, low access to modern cooking fuels (such as LPG) presupposes the continuous use of traditional biomass with their associated health risks. The LPG access rate is far below the ECOWAS target of 50% modern cooking fuels and the MDG target of reducing to 50% those without access set by United Nation’s Millennium Project. There is scant data on the improved cook stoves in the country. It is therefore difficult to measure how their availability is making up for the limited LPG use in the country.

From the above situation, a low access rate of cleaner cooking fuels (LPG, improved cook stoves etc) may therefore present a potential threat to achieving MDGs. The situation is likely to be worsened in the Northern, Upper East and Upper West regions of Ghana where the number of LPG stations is extremely low (see Figure 4.4). For instance it is estimated that, an average of 51,444 people are served by one LPG station in the Greater Accra region which is almost eight times less than Northern region where a population of 411,426 are served by one LPG station. Although the number of LPG station access across Ghana is inadequate, the situation in the three Northern regions (Upper East, Northern and Upper West) is very bleak as the LPG stations are concentrated in the regional capitals. The difficulty of access to LPG by remote settlements (from the regional capitals) is evident in the large land areas/sizes of the regions coupled with the persistent transportation problems. This presupposes the high dependence on traditional biomass in the aforementioned regions. In effect, not until LPG access rates are increased to an appreciable level, achieving MDGs will be difficult.
4.4 Drivers of Ghana’s Energy Access

4.4.1 Long-term planning with clear targets

The study has also unveiled the driving forces of the country’s quick strides in energy access particularly electricity between 1990 and 2010. An important driver of Ghana’s strides in electrification is a consequence of long-term planning with clear targets. The country has been one of the few African countries which have set up energy planning policies with clear targets sometimes with future projections close to 3 decades. For instance under the NES which was set up in the 1990, the country laid out its quest for universal electrification (100% access) by 2020, which the current government is still pursuing. The Scheme which appeared over-ambitious at the outset has been a significant driver of electricity access especially through discrete programs such as the Self-Help Electrification Scheme (SHEP). Indeed, Ghana’s electricity access rate has been spurred by the SHEP. Under the SHEP, clearly stated significant contributions/commitments are expected from both the government and communities willing to get connected to grid electricity. Under the SHEP, residents of non-electrified communities mobilize resources for electrification having met the three cardinal pre-requisites described above.

![Population per LPG station in Ghana](image-url)
4.4.2 Availability of external funding

Availability of external funding has been an important driver of Ghana’s phenomenal energy access rate. Although a reasonable amount of financial resources have been made by the government of Ghana towards energy access in the country, availability of funding from European and Asian countries have facilitated the implementation of Ghana’s energy projects. Without the funding, the country could not have made such a big leap forward in energy access. The Northern Electrification and System Reinforcement Project (NESRP) which is one of the forerunners of Ghana’s electrification programmes was funded by the African Development Bank in 1987. The same can be said about GEDAP. Currently a GIS-based Energy Access Project (GIS-EAP) in Ghana at The Energy Center of Kwame Nkrumah University of Science and Technology (KNUST), Kumasi is funded by the European Energy Initiative-Partnership Dialogue Facility (EUEI-PDF) based in Germany. The GIS-EAP has produced interesting results of cost-effective electrification options (grid, Solar PV and diesel mini-grid) for 30%, 60% and 100% penetration rates in Ghana in 2020 using the Network Planner model developed by the Earth Institute of Columbia University. To achieve 100% electrification rate in Ghana, the Network Planner estimates the cost of US$405,666,052. The 10 years time horizon (2010 as a base year) was used as basis for the electrification cost estimation due the country’s desire to achieve universal electrification by 2020.

4.4.3 Politics/popular demand

Electricity access in Ghana has been observed over the years as influenced by electioneering years where efforts for rural electrification are a major vote-winner. Political commitment is thus very high because parliamentary candidates have been known to spend their own or campaign funds to extend grid distribution lines to their constituencies even in cases where there was no power flowing through the wires. Presidential candidates’ especially incumbent parties have similarly contributed to electrification. It was also revealed that electrification (grid electricity) has been a popular supplication electorates present to their respective political candidates during elections before giving them their mandates. As the country approaches another electioneering year, new sets of electrification programmes are being inaugurated by the incumbent government.

4.4.4 Grid/Utility-based electrification

Ghana’s increased electricity access has been largely influenced by the presence of the grid network, with the high voltage line covering every region of the country. This was done in the early stages of the electrification drive and has helped speed up the process of extending electricity to every district capital in the country. The utility companies, Electricity Company of Ghana (ECG) and Northern Electricity Department of the Volta River Authority (NED-VRA) in collaboration with Ministry of Energy and Energy Commission have made phenomenal contribution to electricity management in Ghana in terms of extending the grid to all parts of the country. The management of the electricity has been less burdensome as the two utility
companies are in charge of power supply in different parts of the country, ECG for the six regions in southern Ghana (Greater Accra region, Ashanti region, Volta region as well as Eastern, Western and Central regions) and NED-VRA for the four regions (Brong-Ahafo, Northern, Upper East and Upper West regions).

4.5 Potential threats

4.5.1 Grid vs Solar!

The study has also addressed the major threats or factors that present bottlenecks to Ghana’s energy access. The electricity companies in Ghana, (i.e. the Electricity Company of Ghana, ECG and the Northern Electricity Department, NED) reveal that, residents of their operation areas have rejected off-grid electrification was being implemented due to the high interest in grid electricity. Interestingly, the reason for such lack of interest is not reducible to only financial reasons but more importantly the maintenance of batteries, regular cleaning of solar panels (to avoid reduced intensity of the solar radiation) including other logistics for Solar PV systems and the repairs of diesel generators coupled with the high fuel costs associated with diesel mini-grid electrification. Energy stakeholders meeting and Sensitization workshop organized by The Energy Center of KNUST reveal that, the lack of interest in the solar energy results from its inability to power electrical appliances such as TV sets, refrigerators, electric irons etc. This limitation, which featured prominently, urged them on for the popular preference for grid electrification. The use of refrigerators for small scale usually home-based economic activities such as sale of frozen fish, soft drinks, iced water, etc., which are impossible with the solar energy was the unanimous reason. Grid was thus mentioned as the obvious choice for those residents whose livelihoods depend on the use of fridge.

Some participants expressed their wish to switch to any of the off-grid electrification options (solar or diesel generator) due to regular grid power outage/cuts at certain critical periods but the capital and recurrent costs presents a major obstacle and thus compelled them to stay on the grid, which is usually overly subsidised by the government. Most people who have had experience with the use of solar energy in their homes or adjacent towns explained that they saw nothing beyond lighting. Moreover, other communities turn down offers for off-grid electrification options when they observe that adjacent communities are on grid electrification. These cases are reported to be the result of campaign promises made by politicians during electioneering years. Such a situation poses a threat to the smooth pace of Ghana electrification drive as it derailed efforts to electrify isolated and small communities where until a decade or two to come, grid may be economically or physically impossible.

4.5.2 LPG Shortages

In terms of modern energy sources for cooking, there has been high shortage of LPG for cooking especially in the peri-urban and urban areas of the country and the situation is gloomy in the rural areas. Already, a rampant shortage of LPG on the Ghanaian market,
especially in the populous urban centers (Kumasi, Accra, etc.) where LPG is mostly used presents a major setback to achieving the 50% access to LPG by 2015 because there is only four years more to reach the target timeline. One of the principal reasons for the frequent shortages of LPG is perhaps the usage by some commercial and private car users who have adapted their engine systems to use LPG due primarily to the relatively cheaper cost compared to gasoline or diesel. Second, the high initial upfront cost of switching to LPG compared with traditional biomass also discourages its use by customers. For instance, it is asserted that, due to the relative larger number of people (90%) without access to LPG for cooking, they are compelled to use firewood and charcoal to improve their lots (UNDP Ghana, 2002; Ghana Statistical Service, 2005).

4.5.3 Financing

Financial constraints have been another significant impediment to modern energy sources especially for productive activities. The 2004 review of the NES revealed that poor communities were unable to pay their electricity bills and the non-existence of productive uses by poor households featured prominently. It is thus not surprising that households in the least energy consuming bracket (0-50 kWh per month) have their costs heavily subsidized by the government. The situation is even gloomier when assessing electricity for productive activities compared to the developed world where a kilowatt-hour cost of electricity for productive activities is less expensive compared with the cost for residential use, the reverse case exists in Ghana. This puts off prospective businesses that require the use of electricity. Rural enterprises which are expected to revive rural economies from raw materials production to the stage of value addition are beset with the high cost of electricity and thus leading to less remarkable successes in the productive use programme launched by the Ministry of Energy.

4.5.4 Electricity Losses

The grid electricity system losses in Ghana (technical and commercial) was 1774 GWh in 2009. This figure represented 26.8% of the total electricity consumption in the country. On the average, electricity losses in Ghana have hovered around 26.2 % for the period between 2000 and 2009 as shown in Figure 4.5. This is far below the best practice value of about 5% or thereabout. The increased transmission losses have been attributed to the transmission of power from the south to the middle sector and eventually to the north of Ghana due to the absence of power generation plants in the northern parts of the country. The long distance transmission translates into significant losses and stability problems for the transmission network. If reduced to the barest minimum, areas of the country without electricity access due to inadequate electricity power generation could be served with the energy saved through the reduction of the system losses. The faster completion of the Bui hydro power dam in the middle part of the country could help reduce the losses by way of balancing energy transmission inland or a higher transmission like the 330 KV proposed by ECOWAS would be required.
Figure 10: Total electricity losses (commercial and technical) in Ghana, 2000-2009
5  Development of GIS e-maps for Energy Services

One of the key objectives of the GIS-EAP project was to train key staff members of Ghana’s Ministry of Energy, Energy Commission and members of the Multi-Sectoral Group (MSG) on GIS based e-maps and scenarios to continuously update energy data/information for monitoring and implementation. The base maps used in the project were created using the ArcGIS software. Figures 5.1 to 5.8 are GIS e-maps for year 2000 district population, substations of Electricity Company of Ghana, status of electricity connection in communities, Clinics and Hospitals and their electrification status by district, Basic Schools with & without access to Electricity, renewable energy sources such as mini-hydro, radiation and potential wind stations, LPG stations, year 2010 regional population map from the provisional data of the 2010 population census and communities with access to biogas digesters. As of the time of compiling this report, district populations from the 2010 population census is yet to be released.

The number of districts in Ghana has since the year 2000 increased from 110 to 170. Since this increment was done, there has not been any census before 2010 to generate accurate district population map. Some boundaries are still to be clearly demarcated. Provisional figures from the 2010 census was only at the regional level and it was therefore not possible to prepare accurate district population maps until the district population figures are released.

The electrical network of Ghana also show substations for the southern part where data was readily available. Indications are that substations in the northern part have been surveyed and data processing is still ongoing. When available, the map would be updated to cover the substations in the northern parts of the country. Comparing Figure 5.2 to Figure 5.3 indicate that there is a higher rate of connected communities in locations with denser substations.

An overview of Figure 5.5 shows that most basic schools do not have access to electricity. With the exception of about 7 districts, access to electricity by basic schools in most districts is less than 60%. A close observation shows that more than half of the districts have less 21% of their basic schools having access to electricity. This trend is quite worrying and calls for attention. In order to improve teaching and learning, more basic schools must have access to electricity to enable them use modern teaching and learning methods and embrace information technologies that will enhance their skills in the future.

5.1  Soft copies of maps

All maps have been exported to the JPEG format which can be opened on all computers with a picture editor or viewer and hence reprint of maps or their inclusion in reports at later periods will not be a problem. Using the shape files additions, changes can be made to the maps and reformatted to produce new or modified maps as and when new information is obtained. This modification or update can be done using any of the GIS software such Manifold.
2000 District Population Density (Persons/sq.Km) Map

Legend
Population Density
- 16 - 76
- 77 - 155
- 156 - 287
- 288 - 593
- 594 - 1153
- 1154 - 4905
- 4906 - 7801

Figure: 2000 district population density of Ghana
Figure 12: Map showing national electricity grid network
National electrification status map of Ghana

Legend
- Connected Comm.
- Unconnected Comm with Pop 500+

The Energy Centre, KNUST

Figure 13: National electrification status map of Ghana
Data Source: Ministry of Energy, 2011
Figure 14: Forms of energy used by health facilities in Ghana.
Normalised number of Basic schools with access to electricity at the district level in Ghana

Legend
- 0.00 - 0.20
- 0.21 - 0.40
- 0.41 - 0.60
- 0.60 - 0.80
- 0.81 - 1.000
- WaterBody

Key
District: Total no. of schools (no. with electricity)

0 30 60 120 Kilometers

The Energy Centre, KNUST

Figure: Basic schools with and without electricity
Location of key renewable energy sources
Figure: LPG station map of Ghana
Figure 18: Provisional population map from 2010 population census
5.2 Updating of maps

To update and edit the developed GIS maps, any GIS software can be used. However, specialized knowledge in GIS is required to be able to edit the information stored therein and subsequently produce new maps. For this project Manifold System 8.0 would be used for future updates since 5 licenses have been purchased by the project. Currently, The Energy Center would take the responsibility of updating the maps until such a time that The Energy Commission can adequately train their staff to perform this function. The minimum qualification required for the training is:

- Advanced knowledge in Microsoft Excel
- Advanced knowledge in the GIS and related application for mapping and analysis

An overview of the use of ArcGIS to edit the information was explained to the staff of Energy Commission, Ministry of Energy and other allied agencies during the training programme that was held for them. A detailed training program is necessary to enable them take over the editing and updating completely.

5.3 Map Operation and maintenance manual

A manual has been prepared for end users in ArcGIS for basic editing, querying, navigation and updating of the e-maps. The manual comes in both English and French versions. The English version of the manual can be found in Appendix 1.
6 Development of Methods and Tools for Capacity Building

6.1 Electricity pre-feasibility modelling using network planner

Due to high cost of investment, policy makers and planners need tools to develop strategies for lowering the electrification cost in order to meet the economic demand of the region. Electricity utility agencies mostly focus on the intensification of electricity access to urban areas already covered with existing grid network and rural areas within reasonable distance (20km) from an existing electricity grid network. If these policies are to be retained then electrification to new areas will advance at a slower pace or even be neglected. Rural electrification is generally considered to be not cost effective due to factors such as low population density coupled with large dispersion of households, low demand and persistent poverty.

6.2 Model application - The case of Ghana

The Network Planner model was applied to the case of Ghana for the expansion of electricity access to communities that are not electrified. The modelling was done on a regional basis to understand the total cost of electrification for the un-electrified communities in each region since each region has different characteristics of some of the inputs model parameter that have to be considered. In this study, the year 2010 was chosen to be the base year coupled with a time horizon of ten (10) years due to the country’s energy target of universal electrification in 2020. All the input model data were acquired in 2010 except the population data of the un-electrified communities which were projected from the year 2000 to the year 2010 using a population growth rate proposed by the Ghana Statistical Services.

During the modelling exercise, the following assumptions were considered as the base scenario: 100% penetration rate, current cost of diesel fuel per litre of US$1.02, 12 hours of operation of diesel mini-grid electrification, an average household demand of 150kWh per year for a population less than 500, and since all the un-electrified communities were rural (population < 5,000); a rural population growth rate was applied to project their population to 2020.

During the sensitivity analysis the following listed assumptions are considered: penetration rates of 30% and 60%, cost of diesel fuel per litre of US$1.50 and US$0.75, a mean inter-household distance of 15m, 40m and 100m, and lastly changes in household demands (down to 50 kWh and 100 kWh). For this sensitivity analysis, the Northern and Greater Accra regions were considered. What prompted this selection was because of the variability in population densities of the regions, with Northern region having the least population density and Greater Accra having the most population density. Figure 6.1 illustrates the population densities in Ghana with a multiplier by which Greater Accra is denser. From Figure 6.1, it can
be noticed that the population density of Greater Accra is 45 times higher than that of Northern region.

![Figure](image.png)

**Figure**: Population densities in Ghana with a multiplier by which Greater Accra is denser

### 6.2.1 Communities Analysis

The results obtained from the base scenario which represents the best estimates of parameters and assumptions used in modelling the un-electrified communities in each region are summarised in Table 6.1. The regional maps showing the proposed electrification technology options for the un-electrified communities are shown in Appendix 2.

Table 6.1 shows that by the end of the 10 year period, the most cost-optimized option for majority of the un-electrified communities in each region will be grid connection, accounting for more than 70% of the total un-electrified communities in each region. This can be attributed to the extensive pre-existing grid network coverage over the country, which reduces the distances and thus the costs, to connect remaining communities.

Among the two decentralised options, fewer un-electrified communities (6%) are designated for off-grid electricity (with two regions having no off-grid compatibility). It is worth noting that Northern region has the highest percentage of communities (20%) to be electrified by
off-grid technology, followed by Upper West region (10%). The reason for these high values can be attributed to the low coverage of pre-existing grid network which results in high “remoteness” (defined as the distance from a community to the existing grid network) of the communities in these regions (see the maps of Northern and Upper West regions in Appendix 2). Communities that are located far from the existing grid network tend to be electrified by any of the stand-alone options.

Table 6: Results obtained from the base scenario used for the modelling

<table>
<thead>
<tr>
<th>Region</th>
<th>Number of un-electrified Communities</th>
<th>Percentage of each electricity technology recommended by the model to serve un-electrified Communities</th>
<th>Cost Of Off-Grid (US$) (10yr, initial + recurring)</th>
<th>Cost Of Mini-Grid (US$) (10yr, initial + recurring)</th>
<th>Cost Of Grid (US$) (10yr, initial + recurring)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ashanti</td>
<td>221</td>
<td>Off-Grid 5%, Mini-Grid 15%, Grid 81%</td>
<td>3,121,441, 3,563</td>
<td>8,320,534, 3,224</td>
<td>49,685,160, 2,213</td>
</tr>
<tr>
<td>Brong Ahafo</td>
<td>195</td>
<td>Off-Grid 4%, Mini-Grid 21%, Grid 75%</td>
<td>2,562,549, 3,564</td>
<td>10,327,660, 3,255</td>
<td>48,416,833, 2,152</td>
</tr>
<tr>
<td>Central Eastern</td>
<td>175</td>
<td>Off-Grid 1%, Mini-Grid 3%, Grid 96%</td>
<td>401,384, 3,431</td>
<td>2,229,429, 3,101</td>
<td>54,516,496, 1,886</td>
</tr>
<tr>
<td>Greater Accra</td>
<td>247</td>
<td>Off-Grid 2%, Mini-Grid 6%, Grid 92%</td>
<td>1,701,894, 3,598</td>
<td>3,540,105, 3,192</td>
<td>44,607,487, 2,120</td>
</tr>
<tr>
<td>Northern</td>
<td>660</td>
<td>Off-Grid -%, Mini-Grid 9%, Grid 91%</td>
<td>- - -</td>
<td>438,546, 3,024</td>
<td>2,420,494, 1,760</td>
</tr>
<tr>
<td>Upper East</td>
<td>299</td>
<td>Off-Grid 1%, Mini-Grid 1%, Grid 98%</td>
<td>706,083, 3,395</td>
<td>939,066, 3,109</td>
<td>59,990,598, 1,882</td>
</tr>
<tr>
<td>Upper West</td>
<td>294</td>
<td>Off-Grid 10%, Mini-Grid 9%, Grid 81%</td>
<td>7,709,352, 3,378</td>
<td>7,009,443, 3,229</td>
<td>54,001,590, 2,252</td>
</tr>
<tr>
<td>Volta</td>
<td>179</td>
<td>Off-Grid 2%, Mini-Grid 2%, Grid 96%</td>
<td>1,839,250, 3,444</td>
<td>2,374,145, 3,166</td>
<td>80,057,241, 2,031</td>
</tr>
<tr>
<td>Western</td>
<td>319</td>
<td>Off-Grid -%, Mini-Grid 6%, Grid 94%</td>
<td>- - -</td>
<td>5,997,600, 3,334</td>
<td>95,648,882, 2,126</td>
</tr>
<tr>
<td>High Average</td>
<td>660</td>
<td>Off-Grid 20%, Mini-Grid 21%, Grid 98%</td>
<td>28,575,697, 3,491</td>
<td>16,451,983, 3,302</td>
<td>102,249,319, 2,397</td>
</tr>
<tr>
<td>Low Average</td>
<td>260</td>
<td>Off-Grid 6%, Mini-Grid 8%, Grid 87%</td>
<td>5,827,206, 3,483</td>
<td>5,762,851, 3,194</td>
<td>59,159,410, 2,082</td>
</tr>
<tr>
<td>Low</td>
<td>11</td>
<td>Off-Grid 1%, Mini-Grid 1%, Grid 70%</td>
<td>401,384, 3,378</td>
<td>438,546, 3,024</td>
<td>2,420,494, 1,760</td>
</tr>
</tbody>
</table>

At the national level, the average connection cost per household for grid electrification is US$2,082 and the total cost (capital cost plus recurring costs, including costs of electricity generation which is incorporated in terms of the per kWh tariff paid to meet the electricity demands) amounted to US$591,594,100 for the ten year planning period. The total cost of off-grid electrification for the ten year period amounted to US$46,617,650. However, the average connection cost per household of grid electrification per each region (US$2,082) is lower than the other two stand-alone options. The reason is that off-grid and mini-grid
electrification is generally costly due to high recurring costs, particularly for diesel fuel and replacement batteries for solar PV systems.

It should be understood that costs for grid connections can take advantage of economies of scale: households in a grid compatible community, in effect, share the total infrastructure cost of the initial extension of the medium voltage grid line and transformer to serve the community. The result is lower costs per connection when the grid is extended to larger settlements. In contrast, the cost per connection of off-grid technologies does not typically scale in the same manner. Each solar system installed in an off-grid compatible community costs approximately the same as another system of similar size.

### 6.2.2 Proposed Grid length and Levelised Cost of Electrification (LCOE) Analysis

Table 6.2 shows the required grid extension for the proposed MV and LV lines for connecting households in the communities and the levelised cost per each electrification option in each region.

It can be observed from Table 6.2 that the average levelised costs of grid electrification (US$0.57/kWh) is lower as compared to the levelised costs of the two decentralised technology options – diesel mini-grid (US$1.02/kWh) and solar off-grid (US$1.12/kWh). Here the levelised costs of each technology in each region represent the total cost of electrification of each technology including all recurring costs for the ten year planning duration, divided by the sum of all the electricity supplied in kWh of only those communities designated by each technology in each region.

To a certain extent, the LCOE is inversely proportional to the total electricity demand. Higher demand typically justify investment in technologies that have higher initial costs, but lower long-run costs, at higher density, which tends to lower per unit costs of electricity delivery. This is typically true for the electricity grid: once a grid connection is established for communities, it is relatively inexpensive to provide power to that line, compared with solar and mini-grid, largely due to the high recurring costs of the stand-alone options (batteries for solar, and fuel for diesel). Stand-alone options can, however, have lower LCOE for some communities – particularly smaller communities, distant from the grid – where the high initial costs of grid extension will not prove cost-effective, even when averaged over several years. For these communities, off-grid technologies remain the least-cost option, at least for the limited time horizon (10 years) of this planning exercise.

It is worth noting that, although the LCOE values are higher than typical grid tariffs (average of about US$0.12 per kWh for residential usage), this is largely due to the fact that this computation includes the assumption that all capital expenditures for the grid extension will be repaid within the 10 year time horizon of the model, which is very rapid for this very long-term infrastructure.
Moreover, it is evident from Table 6.2 that the total length of MV and LV-lines needed to connect households in the regions totalled to 7,435,280m (52%) and 6,925,075m (48%) respectively to the total length of grid electrification of all the communities that are proposed to be on grid compatible in each region. In addition, the country requires an average of 27.3m of MV grid length and 24.8 m of LV grid length per household for extending and connecting households in communities in each region that are grid compatible. The decomposition of the total length of MV and LV gridlines per each region needed in connecting communities are shown in Table 6.2. It can be observed that the Northern region has the highest proposed MV and LV grid lines of about 21% and 15% of the total proposed MV and LV grid length for the country respectively; likewise, Greater Accra has the least (that is 0.6% and 0.5% ) of the total proposed MV and LV grid length for the country respectively. This is largely due to fact that Greater Accra is characterised by high existing grid network penetration coupled with high population density. Therefore, communities in Greater Accra are in close proximity to the existing grid network and may require relatively short lengths of MV lines for connecting communities. The reverse characteristics can be attributed to the Northern region.
6.2.3 Cost analysis

Initial costs and total costs (including initial and discounted costs for the ten year period) of electrification in each region are summarised in Table 6.3. Table 6.3 compares the combined cost of all the three electrification technologies under three penetration rates (PR) scenarios: the full penetration rate at 100% – defined as electrification of every household in each un-electrified community in all regions – and the two other rates at 60% and 30%, defined as electrification of all communities in all regions, but including only 60 or 30% of households within each community. To obtain the full penetration rate employing all the three electrification options, the total initial cost is estimated to be US$405,666,052. Comparison of the two other penetration rates reveals total initial costs of US$287,358,895 and US$147,096,023 for penetration rates of 60% and 30% respectively. The total cost of electrification (including initial and recurring) at 100% penetration rate totalled to US$695,840,261 by the end of the time horizon (2020).

Table 6.3: Total and initial cost of all combined electrification technologies at each penetration rate

<table>
<thead>
<tr>
<th>Region</th>
<th>Cost Of ALL ELECTRIFICATION, US$ (Grid, Solar off-grid and Diesel mini-grid)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>PR = 100%</td>
</tr>
<tr>
<td>Ashanti</td>
<td>61,127,135</td>
</tr>
<tr>
<td>Brong Ahafo</td>
<td>61,307,042</td>
</tr>
<tr>
<td>Central</td>
<td>57,147,309</td>
</tr>
<tr>
<td>Eastern</td>
<td>49,849,486</td>
</tr>
<tr>
<td>Greater Accra</td>
<td>2,859,040</td>
</tr>
<tr>
<td>Northern</td>
<td>147,276,999</td>
</tr>
<tr>
<td>Upper East</td>
<td>61,635,747</td>
</tr>
<tr>
<td>Upper West</td>
<td>68,720,385</td>
</tr>
<tr>
<td>Volta</td>
<td>84,270,636</td>
</tr>
<tr>
<td>Western</td>
<td>101,646,482</td>
</tr>
<tr>
<td>TOTAL</td>
<td>695,840,261</td>
</tr>
</tbody>
</table>

It can be deduced in Table 6.3 that the initial costs of all electrification for the ten year time horizon accounted to about 58% of the total discounted electrification costs at both 100% and 60% penetration rates; and to about 46% of the total discounted electrification costs at 30% penetration rate. The remaining percentages of the discounted electrification cost are
recognised as the recurring costs, including operations and maintenance, as well as the cost of electricity paid by consumers.

Figure 6.2 shows a graph depicting the patterns of discounted cost in each region at the end of the ten year period per each penetration rate considered. It can be revealed from the Figure 6.2 that the total cost of electrification at each penetration rate differs widely across regions with the total cost of electrification in Northern region (US$147,276,999) is the highest and that of Greater Accra (US$2,859,040) is the lowest. Costs of electrification in the five regions of Ashanti, Brong Ahafo, Eastern, Upper West and Upper East fall between US$40,000,000 and US$80,000,000, whereas costs for the remaining two regions – Volta and Western – falls between US$80,000,000 and US$120,000,000. Factors that contribute to the high cost of electrification in Northern region include: (i) low existing grid network...
coverage coupled with a large number of relatively remote un-electrified communities. These factors are reversed for Greater Accra, which has the least total cost of electrification. These electrification cost ranges provide a useful guide in planning investments and financing required either from private sectors or the government to achieve Ghana’s objective of universal access by 2020.

### 6.2.4 Sensitivity Analysis

Sensitivity analysis was performed to understand the impact of changes in certain parameters on the model results. Greater Accra and Northern region were chosen as test cases for the sensitivity analysis because they represent two extremes of population density. Greater Accra has the highest population density figure and Northern region the least. The results are shown in Table 6.4 and the rows highlighted represent the base scenario (best estimates of parameters and assumptions, explored in detail in previous sections), while the non-highlighted rows in Table 6.4 represent scenarios run with variation in the following key parameters: Diesel fuel cost, Household (HH) demand, Mean inter-household (interHH) distance and Penetration rate. It should be noted here that, during the running of the scenarios, all other input parameters and assumptions, aside from the afore-mentioned parameters are the same as the base scenario.

#### Effects of diesel fuel cost changes

It can be deduced from Table 6.4 that lowering diesel cost results in a shift in the percentage of un-electrified communities designated for off-grid or grid in the base case to be mini-grid compatible. In the case of Northern region an additional 31% of the un-electrified communities shifted to be mini-grid compatible when the diesel cost was lowered from the US$1.02 per litre (base scenario) to US$0.75 per litre. Likewise, increasing diesel cost results in reducing the percentage of un-electrified communities that are mini-grid compatible, shifting them to either off-grid or grid compatibility. Furthermore, it can be noted that the number of households that are grid compatible increases as the diesel fuel cost per litre also increases and vice versa.

However, increasing the cost of diesel fuel also impacts the costs of other electrification technologies – grid and off-grid. Increase fuel costs increases the total and average household cost of grid electrification primarily because it increases the need for MV grid lines to connect the additional communities that have shifted from mini-grid to grid compatibility. For instance at a diesel cost of US$ 1.50 per litre compared to the based scenario at US$ 1,02, the average connection cost per household for grid extension increased from US$ 2,397 (base scenario) to US$2,527 in the case of Northern region, and from US$ 1,760 to US$ 1,807 in the case of Greater Accra. In the case of Northern region, the required proposed length of MV grid lines for electrifying communities to the pre-existing grid network increases from 28.5m to 41.4m as the diesel fuel cost per litre is increased from US$0.75 to US$1.50. There is a smaller increase in the discounted cost of off-grid per household with increasing diesel fuel cost, as well. This is a direct effect: the off-grid electrification scheme assumes that most power is provided by solar systems, however the electricity for productive uses is provided by diesel gensets, and this cost rises as diesel costs rise.
Table FEHLER! KEIN TEXT MIT ANGEGBENER FORMATVORLAGE IM DOKUMENT..9: Sensitivity analysis results obtained from the modelling

<table>
<thead>
<tr>
<th>Region</th>
<th>Scenarios</th>
<th>Targeted No. of HHs</th>
<th>No. of HHs that are grid compatible</th>
<th>Percentage of Communities by region to be electrified by each technology</th>
<th>Discounted Cost Of Off Grid per HH</th>
<th>Discounted Cost Of Mini Grid per HH</th>
<th>Discounted Cost Of Grid per HH</th>
<th>Total Cost of all electrification combined</th>
<th>Length of Proposed MV Grid Lines (meters)</th>
<th>Length of Proposed LV Grid Lines (meters)</th>
<th>Levelised Costs (per kWh)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Diesel fuel cost</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>$0.75/ litre</td>
<td>55.827</td>
<td>35.011</td>
<td>3%</td>
<td>41%</td>
<td>56%</td>
<td>$3.587</td>
<td>$2.847</td>
<td>$2.153</td>
<td>$135,182,695</td>
<td>28.5</td>
</tr>
<tr>
<td></td>
<td>$1.02/ litre</td>
<td>55.827</td>
<td>42.659</td>
<td>20%</td>
<td>10%</td>
<td>70%</td>
<td>$3.491</td>
<td>$3.302</td>
<td>$2.397</td>
<td>$147,276,999</td>
<td>57.2</td>
</tr>
<tr>
<td></td>
<td>$1.50/ litre</td>
<td>55.827</td>
<td>45.551</td>
<td>24%</td>
<td>-</td>
<td>76%</td>
<td>$3.667</td>
<td>-</td>
<td>$2.527</td>
<td>$152,765,497</td>
<td>41.4</td>
</tr>
</tbody>
</table>

**Northern**

|        | 50kWh | 55.827 | 9,921 | 83% | 2% | 3% | $1.571 | $4.064 | $1.241 | $86,522,988 | 9.3 | 24.7 | $1.06 | $0.93 | $0.71 |
|        | 100kWh | 55.827 | 31,217 | 42% | 10% | 48% | $2.481 | $2.649 | $1.878 | $120,314,681 | 23.8 | 24.7 | $1.08 | $1.06 | $0.68 |
|        | 150kWh | 55.827 | 42,659 | 20% | 10% | 70% | $3.491 | $3.302 | $2.397 | $147,276,999 | 57.2 | 24.7 | $1.10 | $1.02 | $0.60 |

**Mean IntHH Dist**

|        | 15m | 55.827 | 43,537 | 13% | 15% | 72% | $3.529 | $3.206 | $2.288 | $140,711,865 | 38.7 | 14.8 | $1.12 | $1.00 | $0.63 |
|        | 25m | 55.827 | 42,659 | 20% | 10% | 70% | $3.491 | $3.302 | $2.397 | $147,276,999 | 57.2 | 24.7 | $1.10 | $1.02 | $0.66 |
|        | 40m | 55.827 | 40,952 | 30% | 3% | 67% | $3.476 | $3.517 | $2.558 | $156,540,763 | 55.1 | 39.6 | $1.10 | $1.04 | $0.70 |
|        | 100m | 55.827 | 22,863 | 67% | -   | 33% | $3.491 | -     | $3.216 | $188,590,306 | 22.3 | 99.0 | $1.08 | -    | $0.80 |

**Penetration Rate**

|        | 30% | 17,033 | 6,400 | 35% | 32% | 33% | $4.893 | $4.367 | $2.855 | $67,212,069 | 51.4 | 24.1 | $1.14 | $1.03 | $0.68 |
|        | 60% | 33,761 | 19,623 | 25% | 25% | 50% | $3.767 | $3.468 | $2.654 | $103,512,748 | 44.3 | 24.6 | $1.38 | $1.12 | $0.67 |
|        | 100% | 55.827 | 42,659 | 20% | 10% | 70% | $3.491 | $3.302 | $2.397 | $147,276,999 | 57.2 | 24.7 | $1.10 | $1.02 | $0.66 |

**Gr. Accr**

<table>
<thead>
<tr>
<th></th>
<th>Diesel fuel cost</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$0.75/ litre</td>
<td>1,520</td>
<td>936</td>
<td>-</td>
<td>36%</td>
<td>64%</td>
<td>-</td>
<td>$2.525</td>
<td>$1,622</td>
<td>$2,992,294</td>
<td>19.8</td>
</tr>
<tr>
<td></td>
<td>$1.02/ litre</td>
<td>1,520</td>
<td>1,375</td>
<td>-</td>
<td>9%</td>
<td>91%</td>
<td>-</td>
<td>$3,024</td>
<td>$1,760</td>
<td>$2,859,040</td>
<td>30.1</td>
</tr>
<tr>
<td></td>
<td>$1.50/ litre</td>
<td>1,520</td>
<td>1,520</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>$1,807</td>
<td>$2,746,617</td>
<td>33.4</td>
</tr>
</tbody>
</table>

**HII Demand**

|        | 50kWh | 1,520 | 856 | 45% | -   | 55% | $1,393 | -     | $1,127 | $1,880,088 | 6.2 | 24.8 | $1.04 | $0.83 |
|        | 100kWh | 1,520 | 1,115 | 18% | 9%  | 73% | $2,427 | $2,363 | $1,518 | $2,666,243 | 23.0 | 24.8 | $1.09 | $1.06 | $0.68 |
|        | 150kWh | 1,520 | 1,375 | -   | 9%  | 91% | -     | $3,024 | $1,760 | $2,859,040 | 30.1 | 24.8 | $0.97 | $0.56 |

**Mean IntHH Dist**

|        | 15m | 1,520 | 1,375 | -   | 9%  | 91% | -     | $2,865 | $1,601 | $2,616,571 | 30.1 | 14.9 | -    | $0.92 | $0.51 |
|        | 25m | 1,520 | 1,375 | -   | 9%  | 91% | -     | $2,865 | $1,601 | $2,616,571 | 30.1 | 24.8 | -    | $0.97 | $0.56 |
|        | 40m | 1,520 | 1,220 | 9%  | 9%  | 82% | $3,452 | $3,264 | $1,934 | $3,368,102 | 25.5 | 39.7 | $1.11 | $1.05 | $0.62 |

**Penetration Rate**

|        | 30% | 1520 | 173 | 18% | 27% | 55% | $4,088 | $3,643 | $2,217 | $1,070,259 | 44.9 | 24.4 | $1.25 | $1.10 | $0.67 |
|        | 60% | 914 | 671 | 27% | 73% | -   | $3,366 | $1,947 | $2,124,197 | 32.2 | 24.7 | -    | $1.07 | $0.61 |
|        | 100% | 1,520 | 1,375 | -   | 9%  | 91% | -     | $3,024 | $1,760 | $2,859,040 | 30.1 | 24.8 | -    | $0.97 | $0.56 |

**Effects of household demand changes**

Again Table 6.4 revealed that lowering the household demand to 100kWh from the base scenario of 150kWh results in a substantial shift (about 20%) in the number of un-electrified communities that were grid-compatible in the base case toward off-grid compatibility. The percentage of un-electrified communities that were mini-grid compatible remained the same. Further decrease of the demand to 50 kWh shifted an even higher percentage of un-electrified communities from grid or mini-grid...
compatibility toward off-grid compatibility. The overall result of lower electricity demand is a dramatic reduction in grid compatible communities. High demand communities “justify” the large expenditures for the MV line and transformers and other aspects of grid extension, because they will deliver a lot of power to customers over a longer timeframe, thus repaying the initial investment. On the other hand, if demand is very small, it is not really worth spending large sums on major infrastructure. Instead, small demands can be met with small technologies, such as solar systems, that typically have a fairly high cost per watt, but lower investment costs.

Moreover, the average cost per household in the communities that are to be connected with any of the three electrification options shows a direct relation to these demand scenarios with the lowest demand scenario having the least cost per household and the highest demand scenario having the highest cost per household. The main reason is that increasing demand increases the costs of power delivery over the years of operation of any of the electrification system. In the case of Greater Accra, it is realised from Table 6.4 that the average connection cost per household in communities that are grid-compatible at a household demand of 50 kWh is US$ 1,127 and increases to US$ 1,760 when the household demand is raised to 150 kWh. It is observed from Table 6.4 that high demands results in an increase in the number of households; and therefore resulting in a high projected cost of grid electrification and the connection cost per household. More so, total costs are heavily affected by the recurring costs of meeting sustained, higher level demand. The reverse is true when the household demands are lowered.

It can be deduced that household demand and required proposed length of MV grid lines needed to connect households in the communities to the existing grid network tend to rise together. As a matter of fact, the lower the household demand the lower the required MV grid length needed to connect communities and vice versa. In the case of Northern region, it is realised that at a household demand of 50 kWh, the required length of MV grid lines per household of 9.3m is needed to connect the communities. This is about 75% less than 37.2m for the base scenario. A similar situation pertains in the Greater Accra region. The inferences from the above discussion is that at a low household demand, fewer communities tend to be grid-compatible and therefore requires less length of MV grid lines to connect such communities. The reverse is true when the household demand is high. For instance, in the case of Greater Accra, there were 55% of communities that were grid-compatible at 50kWh but rises to 91% when the demand was at 150kWh, an increase of 36%.

**Effects of mean inter-household distance (MID) changes**

An increase in mean inter-household distance (MID) tends to shift un-electrified communities to be off-grid compatible while lower MID shifts un-electrified communities to be mini-grid and grid – compatibility. It can be noted from Table 6.4 that further increase of the MID from 25m (base scenario) to 100m results in no mini-grid communities while lowering MID from 25m to 15m results in a slight increase in the percentage of communities that are mini-grid compatible. In the case of Greater Accra, as the MID is reduced there is a constant percentage of communities (9%) that are mini-grid compatible, even as MID increases. In the case of Northern region, however, there is a gradual decrease in the percentage of communities that are mini-grid compatible as MID increases. This is because the Northern region is the biggest region in Ghana with low population density and less existing grid network coverage. This results in highly dispersed settlements, and a high percentage of un-electrified communities. In this context, communities that are far away from the existing grid network (more remote) which may otherwise be mini-grid compatible tend to be off-grid compatible (rather than grid compatible) when MID is increased. A different trend is visible
for model results for Greater Accra, where increasing MID serves primarily to shift communities from grid compatibility to off-grid compatibility, leaving the mini-grid percentage unchanged at 9%.

Increasing MID tends to increase LV lines length for connecting households in the communities, and thus increase cost of connection per household for both grid and mini-grid electrification technology and vice versa. Meanwhile, the off-grid connection cost per household stays very nearly constant (changing only 1% for the Northern region). Moreover, it can be pointed out that as the MID increases, the required length of MV grid lines needed decreases gradually as the number of grid-compatible communities’ drops significantly (see the case of Northern region as it drops from 72% of communities at 15m MID to 33% of communities at 100m MID). For instance in the case of Greater Accra, the required length of MV grid lines needed for connecting households in the communities reduce slightly from 30.1m (at MID of 15m) to 25.5m (at MID of 40m), a difference of 4.6m.

**Effects of changes in penetration rate**

For this project scenarios with multiple penetration rates were run to address the government policy targeting connection of at least 30% of households in every community in Ghana. From Table 6.4, it can be deduced that at a penetration rate of 100% (base scenario) results in high percentage of un-electrified communities to be grid compatible at a low average connection cost per household. Further reduction of penetration rate to 60% and 30% also shift a significant percentage of communities that were grid compatible to be compatible with either of the two stand-alone technologies. It can be noticed that lowering penetration rate tends to lower the total cost of electrification per each technology option for an entire region, however it increases the connection cost per household. The reason for higher connection cost per household with lower penetration rate is the spread of the same infrastructure costs (such as MV line and transformers required to connect the community) over fewer households. For instance, in the case of Greater Accra, lowering the penetration rate from 100% to 30% reduced the number of households from 1,520 to 460, a reduction of about 70%. Moreover, the connection cost per household is noticed to have increased from US$3,024 to US$3,643 but the total cost of all the electrification is lowered from US$2,859,040 to US$1,070,259, a reduction of about 63%.

Moreover, it can also be seen from Table 6.4 that as the penetration rate decreases, the average required grid length of MV lines needed per community decreases. This can be attributed to the fact that as the penetration rate decreases the overall electricity demand for the communities that are grid-compatible also decreases. The lower the electricity demand level, on average, the more likely a community will be designated as compatible with one of the standalone options. In the case of the Northern region from Table 6.4, the required length of MV grid lines needed to connect communities at 30% penetration rate stands at 1,497m but increased to 3,416m at the base scenario of 100%, a difference of 1,919 m.

The initial cost for electrification of all the technologies options has been illustrated in Figure 6.3 which indicates that it will require an initial cost of not less than US$10,000,000.00 to electrify un-electrified communities in Greater Accra under each penetration rate. This is not a surprise as Greater Accra has the least number of un-electrified communities (11) and therefore has the least initial cost of electrification as compared to others.

At a 100% penetration rate, the initial cost of grid electrification in Greater Accra region stands at US$2,021,299 which is about 2% of the initial cost of grid electrification in Northern region at
US$85,568,248 and about 5% of the average initial cost of grid electrification at US$39,759,563 in the other eight regions (see Figure 6.4).

**Figure 6.4** Comparison of the initial cost for electrification of all the technologies options under each of the penetration rate scenarios

### 6.2.5 Summary of modelling results

The model applied in this project can be used by decision makers and electricity planners to make investment estimates and meet requirements for a range of electrification programs given various technology options, governmental policies, fuel cost and so on. In addition, planners can use this model to identify those un-electrified communities that may tend to be grid compatible and those communities that will tend to be off-grid or mini-grid compatible within the specified time horizon either at national or local levels.

This project has shown that, by the end of ten year planning period (2020), majority of un-electrified communities will be viable for grid expansion with some small number being off-
grid compatible. This is due to Ghana’s pre-existing network coverage reaching the whole country (at least running through every district capital in each region).

It has also been shown that the penetration rate has a major influence on the total cost of all the electrification options as well as the connection cost per household. Lowering the penetration rate tends to lower the total cost of all the electrification whereas the connection cost per households increases since the same overall infrastructural cost is shared among fewer number of households.

It is seen that lowering household demand does not have much influence on the percentage of communities that are mini-grid compatible but shifts greatly the percentage of grid compatible communities to be off-grid compatible. It can also be pointed out that lowering diesel fuel cost per litre results in a higher percentage of diesel mini-grid compatible communities.

Lowering mean inter-household distance (MID) tend to shift more communities to be grid compatible since the households are now closer to each other. Here too, increasing the number of grid compatible communities implies increasing the required MV grid lines per households in order to cater for the additional households needed to be connected. It was revealed that the MID is the deterministic factor of the required length of LV grid lines for connecting households.

### 6.3 GIS-based Energy Access Review (GEAR) Toolkit

#### 6.3.1 Rationale of the GEAR Toolkit

The main aim of this part of the project was to develop software which will serve as a tool to manage the energy access data of Ghana and facilitate easy planning and capacity building. The production of a digital map and a functional geo-database of the facilities would assist in the adequate distribution of energy in the following areas:

- Creation of a Geo-database (spatial/attribute) for the features for Updating, based on their conditions.
- Capturing of the geometric and attribute data of electrified and un-electrified communities etc.
- Update and modification of information concerning facilities for electricity distribution such as electrified and non-electrified communities in Ghana etc.
- Faster and easier retrieval of information for instantaneous use in the area of planning, managing and monitoring of electrified communities and the trend of LPG access in communities.
- Performing spatial analysis on energy information.
6.3.2 The Login System
This is the first interface that allows only authorized users to have access to the program (Figure 6.4). It is a password-protected interface that helps to protect the integrity of the inbuilt structures such as database.

6.3.3 The Main GEAR Toolkit Multiple Document interface (MDI)
The main form houses several other forms embedded to manipulate data on their maps. It serves as both input and output interface by allowing the user to load (input) and display (output) a map format .shp

6.3.4 The Map view interface
This is or viewing spatial data of districts and Regions of Ghana. The map view interface is a static query interface that consists of two major interfaces. The first is the Map container and the second is the map display window. The map container provides the user with a schematic layout of the country Ghana. The map displays the ten traditional regions of Ghana as shown in Figure 6.5.

Each region is assigned a tooltip that displays the attribute information (Name of the Region) when the cursor moves across it. One may click on a region of his/her choice and the system extracts all the spatial information of all communities in the region. The systems then differentiate electrified communities from the un-electrified ones.

Note: Regions/Districts are represented as polygons and Communities are displayed as Points.

Figure FEHLER! KEIN TEXT MIT ANGEGBENER FORMATVORLAGE IM DOKUMENT.23: GEAR toolkit login interface
6.3.5 Query window

The Query Builder is used to apply a definition query to a layer if the user wishes to display features with certain attributes as shown in Figures 6.6 to 6.8. To do this the user can type his/her own expression or he can use the Query Builder to help set up the query expression. However, the queries generated are basically through database extraction in ArcGIS 9.2.
Figure 25: A query section in query window

Figure 26: A query analysis window
6.3.6 National statistics window

The national statistics window (Figure 6.9) is a multipurpose window that displays the current electrification state of communities with respect to other districts. It also represents the national statistics on electrification. It can also be used to make analysis on the country’s energy access. The database is also equipped with detailed modelling results from the Network Planner Model. For non-electrified communities these include: cost of electrification using different technologies, cost of components depending on the technology, length of medium voltage and low voltage lines, projected population information, electricity demand data for the community, etc.
6.3.7 Help window/ manual for users of the Toolkit

A help window has been built into the toolkit to enable users easily navigate through the system. A manual has been developed for the use of the toolkit. This manual is also available in English and in French. The English version of the manual can be found in Appendix 3.

6.3.8 Testing the system

A user can log into the system either as an Administrator or a Staff. An *administrator* has complete access to the system while a *guest* user has limited access to some controls.

The user has the privilege to carry out the following operations on the GEAR Toolkit.

1. Query the system to know the electrified and un-electrified communities in a region. E.g. Ashanti Region

   **Type of analysis:** - Database Extraction

   **Syntax Model:** ([Select Region] =“Greater Accra Region”) and ([Select Operator] =“Equals”)

   then press the query Button

2. Query the system to know electrified and un-electrified communities in a particular district

   **Type of analysis:** - Database Extraction
Syntax Model: ([Select Region] ="Ashanti Region") and ([Select Operator] ="Equals") ([Select District] = “Ejura Sekyere Dumase”) then click the Query Button

3. Query the system to select a Particular Community eg, SekyiKouroum in the Kwawu North district of the Eastern Region of Ghana

Type of analysis: - Database Extraction


The system then displays the information from the Geo-database in the form of a table below the Query Builder. The user then selects the community in the system together with the attribute information. The user then have the chance to find out whether the community is electrified, the population of the community, the spatial coordinate of the community, grid Installation cost (US$) and proposed electrification technology for the community if it is un-electrified.
7 Sensitisation and Information Exchange Meetings

During the course of implementing the project, sensitization and information exchange meetings were held between the project personnel of The Energy Center (TEC) and some staff of the Energy Commission, Ministry of Energy, Utilities, District Planning Officers, etc. There were five (5) meetings/ workshops in 2011 as stated in section two of this report. These were the Stakeholder meeting, Sensitization of District Planning Officers, Steering Committee Meeting and trainings for Ghana’s Energy Commission, Ministry of Energy and ECOWAS representatives.

7.1 Stakeholder meeting

A stakeholder meeting was held on 2 and 3 June 2011 at The Energy Center. The purpose of the meeting was to validate data used in the modelling exercise and to discuss the challenges in data acquisition in Ghana. After a lengthy discussion on the presentations, the following recommendations were made for further studies:

1. That the Energy Commission should collect household electricity access and cooking fuel projection for 2010 from Ghana Statistical Service at community levels. These data should be compared with the real data to be obtained from the 2010 census.
2. That whenever “Access Rate” is stated or quoted, the type of access rate (community, household or population access rate) should be defined or clarified in a footnote.
3. That the ongoing project should work with the existing map which covers the 110 districts in view of the fact that this map was yet to be updated to cover all 170 districts in the country currently.
4. That in view of the inaccuracies in the existing maps, especially with respect to right locations or positions of towns on the maps, The Energy Center (TEC) should spearhead the process to get a creditable GIS map of Ghana drawn. To this effect it was agreed that TEC should acquire tiles from the Survey Department and put expertise together to draw a creditable map which would be used by all including the Survey Department itself. It was thus concluded that all the GIS-based projects should pull resources together to buy the tiles and hire experts to digitize them.
5. For the Population data and future projections, Energy Commission and The Energy Center were tasked to inquire from the Regional Institute for Population Studies (RIPS) at the University of Ghana, Legon and Geography Department at KNUST if they have developed any model on population for Ghana.
6. That free GIS software such as Map Windows and others that are user friendly and are available on the internet should be downloaded for use.
7. Manifold software should be studied and mastered to ensure the full usage of the software. For a start some of the tools already been developed should be tried in the Manifold software.

8. That the Energy Commission should collect data on Island Communities from Inland Fishermen Authority near Adabraka Market and Ghana Statistical Services to aid in the plotting of the Island communities at the right locations on the Volta Lake and not on land.

7.2 Sensitization workshop for Planning Officers

A sensitization workshop was held on 9 June 2011 at the College of Engineering Auditorium for district/municipal and metropolitan planning officers to create a knowledge-sharing platform of Ghana’s energy access for an informed energy planning in their respective places/towns/districts. The workshop was attended by 79 planning officers/ planning officers designates from the ten regions of Ghana. The objectives of the meeting were:

- To present the challenges and findings of the GIS-EAP Project to the planning officers.
- To obtain feedback on local-level experiences of energy access from planning officers.
- To sensitize planning officers on the use of GIS tools (GEAR Toolkit) for energy access analysis in their respective districts/municipalities/metropolitan areas.

7.3 Training workshop for Energy Commission and Ministry of Energy

A training workshop for the staff of the Energy Commission, Ministry of Energy and their allied agencies took place on the 3rd and 4th of the August, 2011 at the premises of the Energy Commission, Accra. The workshop was one of the cardinal objectives of the GIS-EAP project which was to provide training for main energy stakeholders in Ghana based on the findings/outputs of the project. The first day of the workshop was earmarked to give an overview of the project, Introduction to Network Planner Model and Training on how to use the GIS-based Energy Access (GEAR) Toolkit. In the second day, Issues of energy data/information gaps in the country was discussed. Training on the creation of e-maps was also conducted on day two.

Issues that came up following training Day one were:

- A better way to compute Liquefied Petroleum Gas (LPG) access rate should be determined.
- ECOWAS criterion for defining electricity access in member countries should be clearly defined.
- Population per Unit of LPG was suggested as a more accurate measure of computing LPG access because LPG tank capacities vary from place to place.
In almost all the presentations, data gaps featured prominently and were flagged to be thoroughly discussed at a later session.

A yardstick for determining the electricity demand for particular areas like rural, urban and peri-urban areas should be made available by utility companies.

The project team took the participants through a training of the GEAR Toolkit developed by The Energy Center as part of the GIS-EAP project. The main comment that cropped up was the need for an *undo button* to be incorporated into the toolkit application so that users may have the option to go back to the previous window. Also, the toolkit did not capture all the electrified and un-electrified communities in Ghana. This was due to the difficulty in travelling to some very remote locations in the country for data collection.

The training on the second day centered on the creation of e-maps using ArcGIS. Topics covered included:

- Exploring geographic data on energy in ArcMap
- Classifying, symbolizing, and labelling map features to improve map visualization and interpretation
- Creating LPG data from x,y coordinates
- Performing spatial analysis
- Querying and analyzing GIS data
- Creating quality e-maps for presentation

One of the important discussion sessions in the second day was energy data/information gaps. Data has been a major challenge of the GIS-EAP.

The following issues featured prominently as important in addressing energy data gaps.

1. Involvement of all energy stakeholders should be an important way forward. It was further stated that if there is a problem making contacts with such important institutions, appropriate government bodies such as the Ministry of Energy could be notified to make the necessary follow ups.

2. It was also raised that, some agencies make huge financial commitments in their research projects/research works and thus feel reluctant to share data or information for free. Unfortunately, project budgets rarely consider funding for data purchases. To address this challenge, it was suggested that, if some financial commitments be paid, there is the need to create that platform properly. A case in point is an initiative by a World Bank research team who have now decided to allocate a reasonable portion of their research fund for data collection. A similar decision could be initiated by project coordinators/managers at research institutes to minimise the constraints in data collection/sharing.

3. Data requests should be nicely presented in such a way that it would be mutually beneficial to both parties (that is the research body and the agency releasing the data). Such mutual interest could facilitate the data or information sharing. It was suggested that access to data/information would be easier with the said approach. A proper or
clearly stated checklist should also be attached to the request. In addition, it was suggested that, data requests should be formalised through the appropriate agencies so that the appropriate data sets or information pieces could be obtained.

4. It also brought forth that most agencies seldom submit energy information data to PURC as they have to. That is another impediment. However, the Right to Information Bill which is expected to streamline access to information is still yet to be transformed into Law. It was thus suggested that the Bill be transformed into a law within the shortest possible time and also institutionalise energy information/ statistics units at ministries/agencies. Such statistics/ information units need to be committed/ dedicated.

5. There is a poor attitude towards record keeping in all aspects of our life and this is transferred to our various institutions/offices. It was explained that, building a comprehensive energy meta-data about what data set is needed, where it will be found and who to be contacted and others would help the energy sector facilitate data collection.

6. Proper contacts need to be made with allied institutions right at the incipient stages, probably in the form of workshops, seminars etc. to get them informed about project objectives and others so that, when follow-ups are made in much later days, they would be more willing to facilitate data sharing/collection.

Participants at the training promised to follow up with their superiors to chart a path towards making the difficulty in data acquisition a thing of the past.

7.4 Training workshop for ECOWAS/ECREEE

A training workshop, similar to the one conducted for the Energy Commission, was organized for country representatives from the ECOWAS region between 22 and 23 August 2011 at The Energy Center, KNUST. This training was jointly conducted with the ECOWAS Center for Renewable Energy and Energy Efficiency (ECREEE) and also included a training session on RETScreen software. In all, there were 60 participants at the ECOWAS training with at least three representatives from each of the 15 ECOWAS member countries. The ECOWAS/ECREEE training focused on steps that could be taken to implement the project and member countries that would be interested. The project team therefore took participants through all the stages that they went through in order to arrive at the project results. The training generated much discussion and participants expressed interest in pursuing similar studies in their countries, counting on the support of The Energy Center and ECREEE.

7.5 Future project implementation in ECOWAS

Upon their request, a concept note has been submitted to ECREEE on further training as a follow up to the training at The Energy Center. The overall goal is to train energy experts in
ECOWAS and the sub-region to use Geo-Information Technology for Energy Planning. Specifically, it aims at Training the energy experts in ECOWAS and the sub-region

- to develop a comprehensive database on Energy at various levels in their respective countries
- build and/or maintain a geoportal for the dissemination of the information above
- develop an interactive computer-based Decision Support System (DSS) in the form of a toolkit to compile, analyze and present data for Energy planning, management and Monitoring

The project team is expecting to receive feedback from ECREEE on the way forward regarding the concept note and future activities.

A project implementation template has also been developed for the ECOWAS Commission (see Appendix 4). This template is expected to guide the implementation of similar projects in ECOWAS member countries which are interested in GIS for energy access planning. The proposal for the project has already been placed on the ECOWAS Regional Portal on Access to Energy Services (http://energyaccessafrica.org/).


8 Conclusions and Policy Recommendations

8.1 Conclusions

The review and assessment carried out has shown that Ghana has made significant strides in electricity access due to long-range energy planning with clear targets, availability of external funding, political/popular demand and active role of central government in the implementation of energy policies. With urban electricity access rate of about 99% and rural access of 49%, the country has made a very good progress when compared with the ECOWAS target values of 100 for urban and 36% for rural households by 2015. This suggests that, Ghana is well on the way to meeting the ECOWAS targets for electricity especially in higher-income regions like Greater Accra and Ashanti. Although, Ghana’s high electricity access rate of 72% places the country at an enviable position, with improved prospects for achieving the MDGs, in comparison with other countries in the sub-region. Nevertheless, the limited use of electricity for productive activities may not yield corresponding spin-off effects on economic development.

Access rate to LPG was low, at approximately 12%. Due to the health effects of traditional cooking fuels, the low LPG access rate present a potential threat to achieving the MDGs. Generally, LPG stations in the country are inadequate to meet the rising demand and recent shortages have even compounded the problem. Current trends indicate that government may not be able to meet its LPG target of 50% access by the year 2015. Cookstove programmes are uncoordinated and data is scanty on their contribution to the reduction of traditional biomass use in Ghana. Even though the Gyapa stove is being highly patronized in the country, data on the numbers disseminated so far is not available for any effective assessment.

Ghana is thus on the path to meeting the electricity targets set by ECOWAS even before 2015. However, not until access to modern cooking fuels (LPG, etc.) and improved cookstoves is increased and electricity is increasingly used for productive activities, Ghana’s enviable energy access may not make a correspondingly meaningful impact on MDGs and economic development.

Even though renewable energy resources abound in the country, their exploitation has been rather low. Ghana has enough solar, wind and mini-hydro resources to provide off-grid and mini-grid solutions to meet rural electrification challenges but these opportunities have not been explored to the extent to which it should. Electrification options using biomass resources have also not been given due attention.

This project has shown, with the aid of electrification modelling, that by the end of the ten year planning period (2020), the majority of un-electrified communities will be viable for grid expansion with some small percentage number being off-grid compatible. This is due to the Ghana’s pre-existing network coverage reaching the whole country (at least running through every district capital in each region).
Sensitivity analysis has also been done to show that the penetration rate has a major influence on the total cost of all the electrification options as well as the connection cost per household. Lowering the penetration rate tends to lower the total cost of electrification whereas the connection cost per households increases since the same overall infrastructural cost is shared among fewer number of households. It is seen that lowering household demand does not have much influence on the percentage number of communities that are mini-grid compatible but shifts greatly the percentage number of grid compatible communities to be off-grid compatible. It can also be pointed out that lowering diesel fuel cost per litre results in a higher percentage of diesel mini-grid compatible communities. Lowering mean inter-household distance (MID) tends to shift more communities to be grid compatible since the households are now closer to each other. Here too, increasing the number of grid compatible communities implies increasing the required MV grid lines per households in order to cater for the additional households needed to be connected. It was revealed that the MID is the deterministic factor of the required length of LV grid lines for connecting households.

The GEAR Toolkit developed in this project will serve as a tool to manage energy access data for Ghana and facilitate easy planning and capacity building. The production of digital maps with a functional geo-database of the facilities would assist in promoting the adequate distribution of energy through various means such as: creation of a geo-database (spatial/attribute) with features for updating; capturing of the geometric and attribute data of electrified and un-electrified communities; updating and modifying information concerning facilities for electricity distribution such as electrified and non-electrified communities in Ghana; faster and easier retrieval of information for instantaneous use in the area of planning, managing and monitoring of electrified communities and the trend of LPG access in communities; and performing spatial analysis on energy information. A user can find information on whether a community is electrified, the population of the community, the spatial coordinates of the community, grid installation cost (US$) and proposed electrification technology for the community if it is un-electrified, etc.

The GEAR toolkit will be hosted on the TEC website so that planners from Ghana, the ECOWAS region and any other country can freely download the Toolkit from the website and browse through the features. The details of the website will include product information, downloading of software and manual, help pages, point of contact, etc. The website would enable the project team stay in touch with users of the product and assist in addressing any concerns that may arise or recommendations for future updates.

Training workshops have been held for energy practitioners in Ghana and other ECOWAS member countries to bring them up to date on the outcome of the project in Ghana and how similar projects could be implemented in ECOWAS countries. Two training workshops were held, one in Accra and the other in Kumasi on 3-4 August and 22-26 August respectively. The Accra training was held for staff of Ghana’s Energy Commission and Ministry of Energy as well as staff from other allied agencies such as the utilities. The Kumasi
training was conducted, together with ECREEE, for energy practitioners from ECOWAS member countries, including a few from training agencies who could be supported to develop similar toolkits and conduct further training sessions in their respective countries.

8.2 Recommendations

A number of recommendations coming out of the results presented in this report include the integration of Solar PV and other renewable energy systems in national electrification programmes, harmonization of energy access data, the need to reduce system losses, sensitization workshops on energy, the need to address LPG shortages, need for database for energy access as well as the need for efforts to address data collection/sharing challenges.

8.2.1 Addressing weaknesses in the current energy supply system

Measures to address power system losses, both technical and commercial, must be sought in order to reduce such losses. The total grid electricity system losses in Ghana was 1774 GWh in 2009. This figure represented 26.8% of the total electricity consumption in the country. On the average, electricity losses in Ghana have hovered around 26.2 % for the period between 2000 and 2009. In other words, if reduced to the barest minimum, areas of the country without electricity access due to inadequate electricity power generation could be served with the energy saved through the reduction of the system losses. The high system losses have been attributed to the transmission of power over long distances from the south to the middle sector and eventually to the north of Ghana due to the absence of power generation plants in the northern parts of the country; the long distance transmission translates into significant losses and stability problems which can be addressed through the siting of power plants in more distributed/embedded manner across the country (e.g. Bui hydro power dam in the middle part of the country). The high system losses are also attributed to non-payment of electricity bills, including “theft”, which can be addressed with introduction of IT-based metering and decentralized revenue collection approaches.

Another weakness in the current energy system is the frequent shortages in LPG supply. Despite numerous efforts to promote LPG for cooking, biomass consumption is still prevalent. The high cost and shortages of LPG in the urban areas further encourages the use of biomass and thus traditional fuel consumption is unlikely to take a nosedive as expected. The issue of adapting car engines to use gas as a fuel in most urban areas of the country has further worsened the availability of LPG. A number of measures would have to be taken to increase access to LPG including creating a favourable investment environment to attract the private sector into the provision of LPG to ensure a regular and adequate supply to peri-urban and rural areas. Better targeting of LPG subsidies by the government should also go a long way in supporting domestic users of LPG for cooking and hence reduce in-door pollution and the accompanying health risks.
8.2.2 Integration of Renewable energy systems in electrification programmes

There is the need to ensure a proper integration of Solar PV and other renewable energy systems into electrification programmes at both national and sub-national levels. In some cases, as with most parts of Ghana, grid-connected solar PV systems can be employed so that the problems associated with the promotion of off-grid electrifications options in soon-to-be-electrified areas would be avoided or at least reduced.

The use of planning tools like the Network Planner should also be promoted to determine which areas are best suited for grid electrification, mini-grids and decentralized options like Solar Home Systems (SHS). The Network Planner software itself also needs to be upgraded so that it can consider more mini-grid and decentralized options in addition to diesel gensets and SHS. In many places small hydro, wind and bioenergy-based power plants could be employed in the roll-out of mini-grids, and small wind turbines could also be used in decentralized home systems. An upgraded Network Planner capable of handling many more renewable energy options is therefore highly recommended by this project.

This would help to increase access rates because grid electricity which is the most preferred option cannot be possible in all non-electrified communities now due to economic and physical accessibility constraints. It is important that communities are educated on the importance of mini grid/ off grid electrification solutions and made to understand that these are not ‘second hand’ solutions as the case has come to be in the case of solar PV home systems. Going forward, politicians must be sensitized to desist from promising ‘grid’ electricity to remote communities where the costs are likely to outweigh the benefits in the short term.

8.2.3 Need for dynamic and shared energy access database

There is a need for more studies to generate a database for determining the pattern of energy access improvement over the years, challenges and prospects as well as the main drivers of energy access in the country. This will help provide useful information for accurate projections about how to achieve a certain time-bound access rate given certain sets of prevailing conditions especially on LPG. For instance, due to the limited data on LPG, the government’s commitment to spur on LPG access rate seems to be a mere wishful promise/projection instead of using evidence-based or realistic data on the pattern of change in access to LPG use and access. This amply raises questions about the government’s plan to achieve 50% access to LPG in 2015 whiles the current rates hover around 12%.

One of the problems that featured prominently during the GIS-EAP project was the difficulties in collecting energy-related data, socio-economic, demographic and spatial/geographic data sets for the evaluation of Ghana’s current energy needs and future projections. Various research projects at The Energy Center (TEC) have also exposed difficulties in obtaining the necessary data to monitor progress of Ghana’s energy access.

The project team also faced problems with inconsistencies regarding specific data sets and years when they were collected. There was also the non-existence of some geographic and demographic data such as mean inter-household distance, average rural and urban
population growth rates at the regional and national levels as well as average rural and urban household sizes across the ten regions of Ghana. These data sets were needed especially to compute realistic projections of population growth and their corresponding energy demands to guide policy formulation.

Data from different institutions/sources should be harmonized. For instance, there is a mixture of electricity access data: coming from Ghana Living Standards Survey (GLSS), Housing and Population Census and Ministry of Energy bearing different computational methodologies. It is therefore suggested that the data sources should be given proper time-stamp and a methodology for computation agreed to allow a good historical (trend) analysis to provide a more nuanced report on the trend of energy access rates at the community/district/municipal/metropolitan levels.

An idea of setting up an Energy Access Data (EAD) Task Force came up during the Stakeholder Forum organised for representatives from the Ministry of Energy (MoEn), Energy Commission (EC) and the distribution utilities (VRA/NED and ECG). The intent of the proposed EAD Task Force is to facilitate the development of a shared database using harmonized methodologies on access to electricity and LPG in Ghana.

Specific objectives of the EAD Task Force will include:

i) Collation of all the data required to monitor progress in the implementation of energy access programmes in Ghana, and

ii) Analysis of energy access data to provide timely information to Government and other stakeholders on prospects for achieving Ghana’s energy access targets.

The EAD Task Force will initially consist of the following agencies (with the power to co-opt additional members as needed):

1. Energy Commission (Convener and Chair);
2. National Petroleum Authority;
3. Volta River Authority/Northern Electricity Department;
4. Electricity Company of Ghana;
5. Ghana Statistical Service;
6. The Energy Center, KNUST
7. CERSGIS, University of Ghana

The project director has recommended the formation of the EAD to the Minister of Energy and a forum for Energy-sector Board Chairs and CEOs and they have agreed to form the EAD Task Force.

This project recommends Msc/Mphil and PhD research works to address the aforementioned data gaps to complement extant studies. The project also recommends further research into the energy demands by specific sectors of the economy such as health and education to facilitate sectoral energy access evaluation. In particular, it is recommended
that further studies be undertaken on the availability of improved cook stoves in households and the improvements made so far across the ten regions of Ghana.
9 Bibliography


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